ANNALS

OF

SURGERY

A MONTHLY REVIEW OF SURGICAL SCIENCE AND PRACTICE

EDITED BY

LEWIS STEPHEN PILCHER, M.D., LL.D.,

OF NEW YORK

WITH THE COLLABORATION OF

SIR WILLIAM MACEWEN, M.D., LL.D.,
OF GLASGOW,
Professor of Surgery in the University of Glasgow.

SIR W. WATSON CHEYNE, C.B., F.R.S.,
OF LONDON,
Professor of Surgery in King's College.

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ANNALS of SURGERY

A Monthly Review of Surgical Science and Practice

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FRACTURES OF THE LOWER EXTREMITY OR BASE OF THE RADIUS . . 1
LEWIS STEPHEN PILCHER, M.D., ... BROOKLYN

VOLKMANN'S ISCHÆMIC PARALYSIS AND CONTRACTURE 28
ALFRED S. TAYLOR, M.D., ... NEW YORK CITY

GUNSHOT INJURIES OF THE PERIPHERAL NERVES AND THEIR TREATMENT 56
HERMANN FISCHER, M.D., ... NEW YORK CITY

CARCINOMA OF THE BREAST 66
JOHN CHADWICK OLIVER, M.D., ... CINCINNATI

AUTOGENOUS FASCIAL RECONSTRUCTION OF THE BILE-DUCT 79
NATHANIEL GINSBURG, M.D., AND JOHN SPEESE, M.D., . . . PHILADELPHIA

SPLENECTOMY FOR REPEATED GASTRO-INTESTINAL HEMORRHAGES 89
DONALD C. BALFOUR, M.D., ... ROCHESTER

ENTEROSTOMY FOR ILEUS 95
CHARLES N. DOWD, M.D., ... NEW YORK CITY

TEMPORARY COLOSTOMY 103
HARRY A. SHAW, M.D., AND JOHN HUNT, M.D., ... SEATTLE

FIBROMA OF THE SMALL INTESTINE RESULTING IN INTUSSUSCEPTION 109
J. E. JAMES, JR., M.D., AND S. W. SAPPINGTON, M.D., ... PHILADELPHIA

TRANSACTIONS OF THE PHILADELPHIA ACADEMY OF SURGERY . . 115
STATED MEETING, HELD NOVEMBER 6, 1916.

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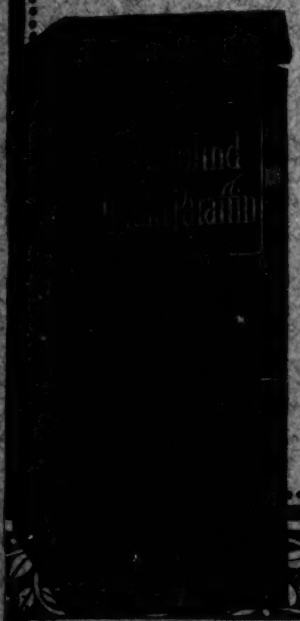

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ANNALS *of* SURGERY

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FRACTURES OF THE LOWER EXTREMITY OR BASE OF THE RADIUS

BY LEWIS STEPHEN PILCHER, M.D.
OF BROOKLYN, N. Y.

FRACTURE of the lower extremity or base of the radius is one of the most frequent surgical conditions that the medical practitioner has to treat. The writer had his own interest first awakened in it as a boy when one of his playmates fell upon his outstretched hand and was picked up with a "broken and crooked wrist." When immediately after graduation he spent some months in a country district looking for practice, he found it when one of his neighbors fell out of an apple tree and sustained a wrist fracture. Again, when some years later, he essayed his fortune in a city he was helped mightily by a friend who had the misfortune to fall down a flight of icy steps one wintry day, and fractured the base of his radius, and by a boy in his neighborhood who, while flying a kite from the roof of a shed, forgot himself, walked off the roof, fell to the ground and wrenched off the lower epiphysis of his radius with extreme displacement. (The condition of this wrist twenty years later is shown in Fig. 110, *q.v.*).

In a service as attending surgeon in the Outdoor Department of a large hospital, which I enjoyed for a period of ten years, 1873–1883, fractures of the base of the radius formed a constant item. The interest thus awakened in that particular injury led me to give to its observation and study much care. Beside a perusal of the literature of the subject, many dissections and experiments on the cadaver were made; specimens in the museums of various hospitals were freely placed at my disposition by their curators for study. In particular a visit to the collection made many years before by Robert William Smith in Dublin, on which was based the treatise of that surgeon on "Fractures in the Vicinity of Joints," was instructive. In the early part of 1878 I published my first paper (Reason *vs.* Tradition in Treatment of Certain Injuries to the Wrist-joint) on the subject in the *Proceedings of the Medical Society*

of the County of Kings, and in May of that year had the opportunity of reading a paper on the same subject, and making an experimental demonstration on the cadaver before the New York Academy of Medicine. In May, 1880, I published a " Further Contribution to the Study of Fractures of the Inferior Extremity of the Radius, etc., (*Proceedings of the Medical Society of the County of Kings,* 1880). In the period which has passed since these publications, more than thirty-six years, my interest in the subject has continued, although in the nature of things other departments of surgical work have engaged more of my attention. I am now returning once more to this subject to make a final contribution to it, in which I hope to embody the mature conclusions of these later years. During this period the Röntgen ray has been added as a source of surgical diagnosis and of observation. Upon no subject has it shed a clearer or greater light than upon wrist-joint injuries. It has been a matter of very great satisfaction to me to find that its revelations have been so markedly confirmatory of the conclusions reached before its assistance was enjoyed. As will be seen in the following pages, I have made full use of the wealth of information which the X-ray skiagrams have produced. Many of these were taken by Doctors Cole and Eastmond and by them freely placed at my disposal. The late Carl Beck was an enthusiast both in the matter of X-ray and in the study of fractures of the lower extremity of the radius, and his valuable material was also generously given to me before his death. The X-ray department of my own private hospital has more recently supplemented and extended the studies for which, before, I had to depend on the goodness of my colleagues.

Naturally I have read with interest the chapters devoted to this injury which have been found in the various treatises on fractures that have appeared during the last quarter of a century; the sound and careful studies of John B. Roberts and the brilliant and convincing work of Scudder deserve especial mention among these, but I have not felt that even by these men the last word has yet been said on the subject in question. I am not vain enough to think that I am myself to say this last word, but I am persuaded that there is still some room for further clarifying and systematizing knowledge and teaching in this field, and as an effort in this direction I offer this contribution.

It may be noticed that I do not use at all the name of the distinguished Irish surgeon which for a hundred years has commonly been attached to this injury. I am influenced in this way by two reasons—one, that names descriptive in anatomical or pathological terms of a surgical condition are much to be preferred when it is possible to phrase

FIG. 1.—The base of the radius and the bones of the wrist—skiagraphs of normal bones—*a*, anteroposterior view; *b*, transverse view.

FIG. 2.—Showing relation of the elements of the wrist-joint when the hand is in moderate dorsal flexion (*i.e.*, extension).

FIG. 3.—Outline from longitudinal section of wrist bones, cut passing through base of radius, semilunar, os magnum and metacarpal bone. Note the projection of the anterior lip of the base of the radius.

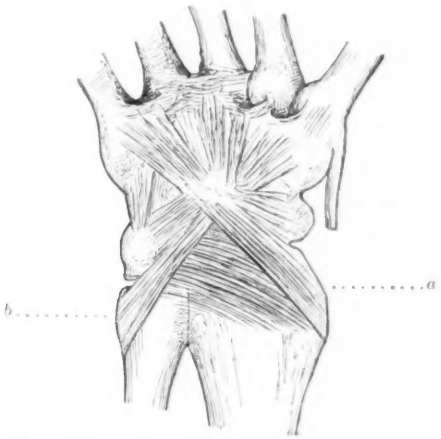


FIG. 4.—Showing the arrangement of the fibres of the anterior common ligament of the wrist-joint. (After Henle.) Note particularly the oblique fasciculi, *a* and *b*, which pass from the mid-carpus outward and upward to be inserted respectively into the styloid process of the radius and of the ulna.

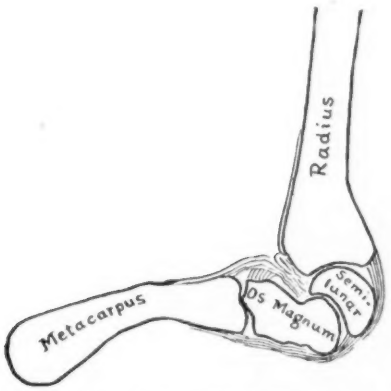


FIG. 5.—Hand in extension: Note the relaxation of the posterior radiocarpal ligament; the rotation and forward projection of the carpal bones, and the tension upon the anterior radiocarpal ligament.

FIG. 6.—Extending force continued: result, extreme backward flexure of the wrist and disruption of the lower end of the radius, the fragment torn off being more or less of that part into which the anterior ligament is inserted.

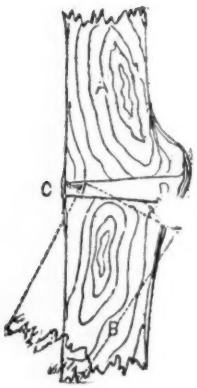


FIG. 7.—The elements of the wrist-joint represented as levers, *A* and *B*.

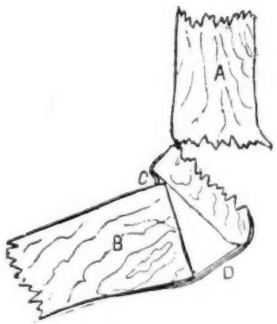


FIG. 8.—Fracture of lever *A* by cross-breaking strain upon lever *B*.

FIG. 9.—The force is transformed into a cross-breaking strain, with the result that the lower end of the bone is torn off (drawing from an experimental specimen.)

them, and, second, because the use of the name in question has been so associated through all these years with erroneous views of the nature and cause of the injury that its continued use tends to hinder the general acceptance now of more accurate knowledge.

That fractures of the lower extremity or base of the radius should be of frequent occurrence one appreciates when the mechanism of its usual production is understood. A fall, and the force of the fall broken by an outstretched arm with hand in extension, are the usual conditions from which it results. In the course of such an accident, forcible bending back of the hand with overtension of the anterior common ligament of the carporadial joint is produced. Strain is brought to bear on the projecting anterior lip of the lower end of the radius (Figs. 2–4). The slipping first row of carpal bones as it moves in the cup-like cavity of the lower articular surface of the radius furnishes the mechanism through which the force is transmuted into a cross breaking strain upon the bone into which the ligament is inserted, with the result that that portion of the bone is torn off (Figs. 5 and 6).

Examine a longitudinal section through the wrist-joint from the middle of the radius to the middle of the third metacarpal bone (Figs. 1–4). The section passes through the semilunar and the outer portion of the os magnum. The carpal bones and the metacarpal are joined together with such firmness that but slight motion is permitted between them. In the movements of extension and flexion at the wrist they act virtually as one bone. At the lower extremity of the radius projects anteriorly a prominent lip, into which is inserted the anterior radiocarpal ligament (Fig. 4), the extent of insertion of whose fibres is continued for a quarter-inch or more above the articular margin. This ligament, though dense and strong, is sufficiently loose to permit considerable latitude of motion backwards of the carpus upon the radius (Figs. 2 and 5). The posterior radiocarpal ligament unites the bones together behind similarly.

The bones thus related constitute two levers. They may be represented as in the accompanying diagram (Fig. 7) by *A* and *B*, held together by bands at *C* and *D*. When *B* is forcibly carried backwards (extension of the hand), the band *D* is made tense; the opposite border of the lever, having slipped forward as far as the band *C* will permit (*cf.* Fig. 2), now abuts against the lower surface *A*, which becomes a fulcrum for the further action of the lever. The mechanical arrangement is such that an immense power may be exerted. If the backward force continues to act, either the band *D* must rupture or a lever be fractured. The projecting lip upon the upper lever puts it at a disadvantage. The

band continues to sustain the strain. The lever gives way (Fig. 8). The point of fracture is necessarily just above that portion of the lever controlled by the band. The strain upon the lever is nearly transverse to its long axis. By this the direction of the line of fracture is determined. A fracture has been produced by definite forces, at a definite point and in a definite direction. These are practically the conditions which unite in the production of the more common fractures of the inferior extremity of the radius.

By the powerful leverage which the extended hand and carpus obtain through the strong anterior ligament upon the lower end of the radius, that portion of the bone is literally torn from it (Fig. 6). The very arrangement of the expanded end, with its cancellated structure, which so admirably fits this portion of the bone for receiving and breaking any shock directly transmitted to it, renders it the less able to resist a force of avulsion. The combination of conditions is such as to make the bone, when submitted to such a strain, weaker than the ligament, and the fracture of the bone accordingly takes place.

Experimental Demonstration.—The truth of this may be easily tested experimentally upon the fresh cadaver by simply bending the hand backward strongly, while the forearm is firmly held, until some structure gives way; this will usually be accompanied by a sharp snap. Upon dissection it will be found that as a rule the anterior ligament of the wrist has remained intact, while the radius has been fractured, the line of fracture anteriorly being found rarely at a point higher than a half inch above the articular edge (Fig. 9). In some instances the ligament will be found to have given way and the radius to have remained intact. In some instances where this occurs, a fracture of the scaphoid or semilunar is produced (Figs. 15 and 24). The lower fragment of the radius in those cases where fracture of that bone has been produced will vary in its shape and in the direction of the line of fracture which it presents. This will be found to bear a constant relation to the strength of the different fasciculi which compose the anterior radiocarpal ligament. In this ligament (Fig. 4) three distinct sets of fibres may be traced, the anterior surface of the scaphoid, semilunar and cuneiform bones affording a common origin; one set (Fig. 4) pass obliquely outward to be inserted into the styloid process and the adjoining anterior margin of the lower end of the radius, these form a dense and strong band, the strongest portion of the ligament; a second set (Fig. 4) pass obliquely in the opposite direction and are inserted into the styloid process and anterior margin of the lower end of the ulna; this band is likewise strong and dense; the third set, forming a

FIG. 10.—Experimental fracture, transverse.

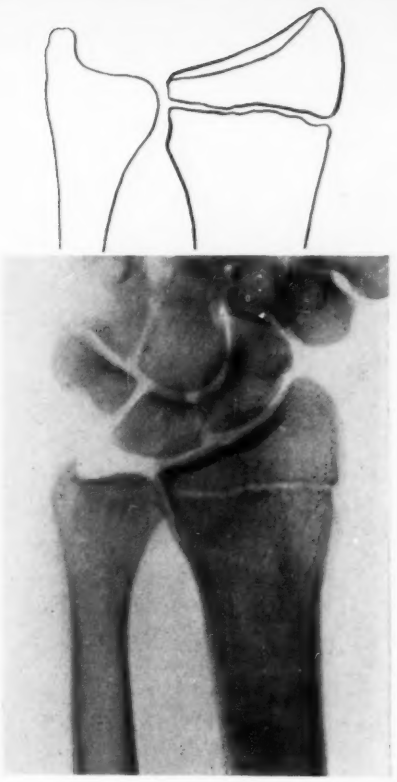


FIG. 11.—Traumatic fracture, transverse.

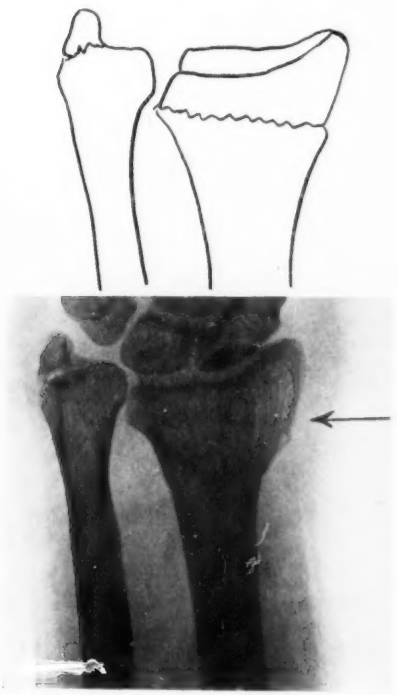


FIG. 12.—Arrow points to line of fracture; lateral view shows radial fragments separated in front, but still held by periosteum behind as by a hinge; angle of separation partly filled with callus. Ulnar styloid fractured.

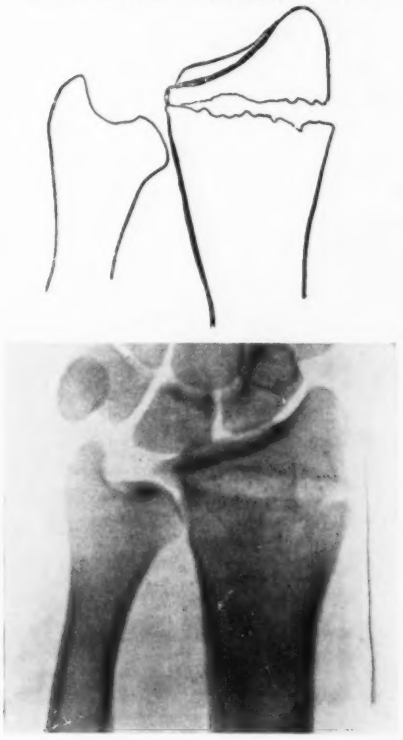


FIG. 13.—Line of fracture somewhat oblique.

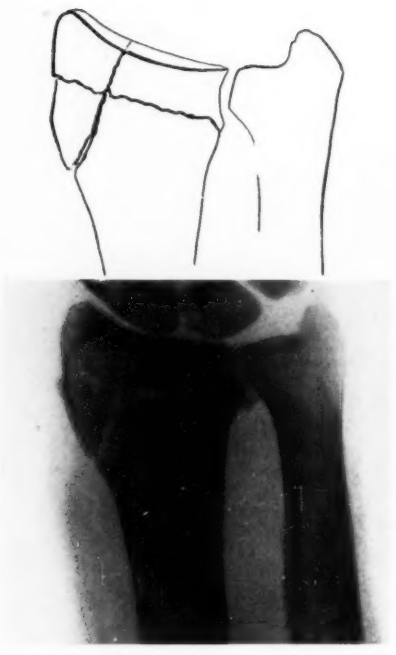


FIG. 14.—A second line of fracture, runs from junction of outer and middle thirds, transverse line upward to base of styloid process. Lateral view shows moderate backward displacement of lower fragments. Mass of callus on dorsal aspect.

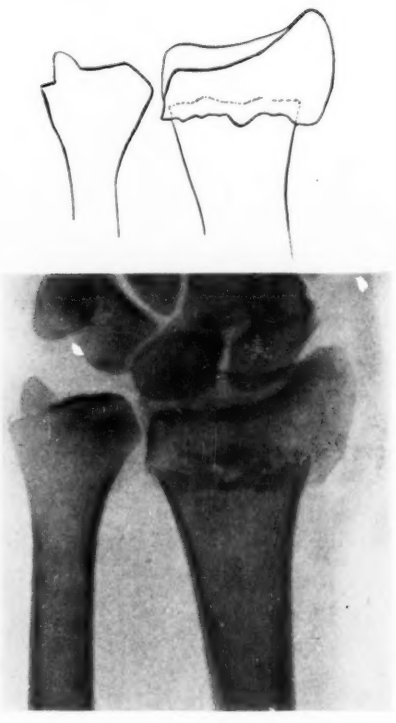


FIG. 15.—Transverse fracture about one-half inch above articular surface. Backward and outward displacement. Fracture of the scaphoid.

FIG. 16.—Transverse fracture in a man of nineteen years who fell a distance of 40 feet. In front the line of fracture is along the epiphysial line; thence it runs backward and upward so that on the dorsum the line of fracture is one inch above the articular edge. The lower fragment is comminuted. (Anterior view.) (N. Y. Hosp. Mus. No. 124.)

FIG. 17.—Transverse fracture with wedge impaction of upper into lower fragment. Comminution of lower fragment. (McGraw's Case, *Annals Anat. & Surg.*, vol. iii, 116.)

FIG. 18.—Transverse fracture with marked backward tilting of lower fragment. (Anterior view.) (N.Y. Hosp. Mus. No. 123.)

FIG. 19.—Experimental fracture. Central portion of anterior ligament of wrist ruptured.

FIG. 20.—Tip of styloid process broken off; scaphoid was also fractured transversely at its middle. Result of fall from top of a derrick. (N. Y. Hosp. Mus. No. 125.) See Fig. 34.

FIG. 21.—Experimental fracture, oblique from centre of carpal surface to base of styloid process.

FIG. 22.—Fracture of base of styloid process. (N. Y. Hosp. Mus. No. 127.)

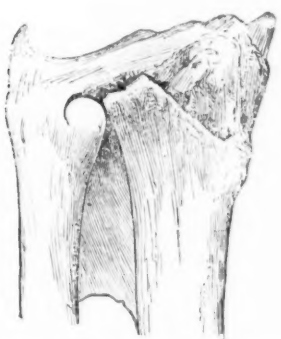


FIG. 23.—Oblique fracture running from junction of inner and middle thirds of articular surface of radius to a point seven-eighths of an inch above tip of styloid process. Lower fragment comminuted. (Anterior view.) (N. Y. Hosp. Mus. No. 122.)

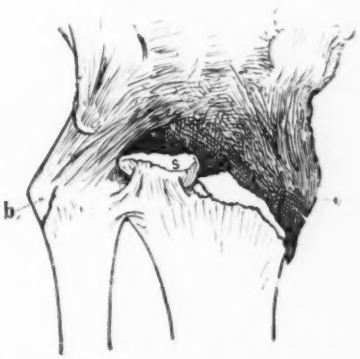


FIG. 24.—Oblique fracture running from ridge on middle of carpal articulating surface to base of styloid process. Transverse fracture of semilunar bone. Fracture of styloid process of ulna. (Wm. Hunt, *Annals Anat. & Surg.*, vol. iii, 112.)

FIG. 25.—Oblique experimental fracture.

FIG. 26.—Oblique traumatic fracture. (N. Y. Hosp. Mus. No. 121.)

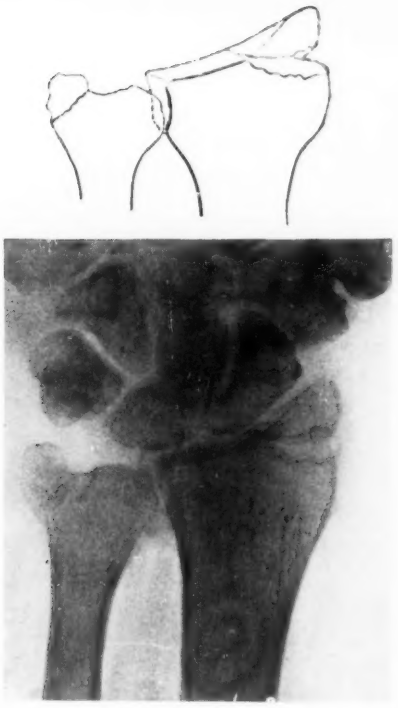


FIG. 27.—Fracture of styloid process of radius and of ulna (automobile crank kickback). Lateral view shows a crush of the posterior lip of the radial articular surface.

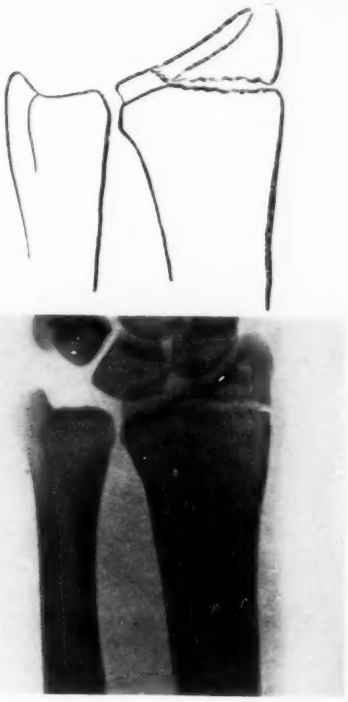


FIG. 28.—From middle of carpal articular facet to the base of the styloid process. No displacement.

FIG. 29.—Line of fracture begins three-fourths inch toward ulnar side of carpal facet and passes outward with slight obliquity to the base of the styloid process.

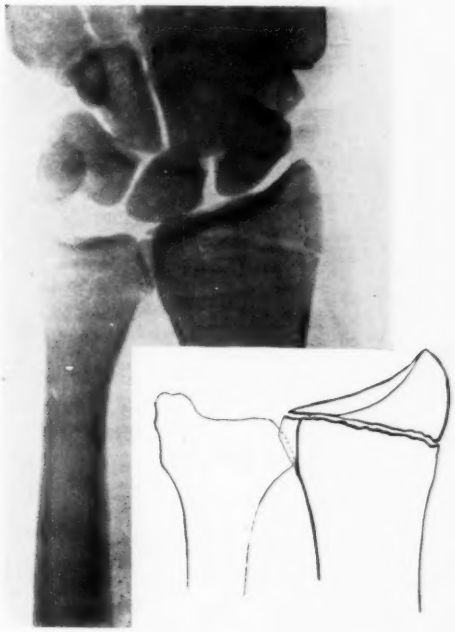


FIG. 30.—Line of fracture from junction of ulnar and carpal facets to base of styloid process. Lateral view shows hiatus between the fragments in front while they are still held together by periosteum behind.

broad and less dense band, pass directly upward to be inserted into the greater part of the anterior margin of the lower end of the radius. If both remain untorn—the most frequent condition—the whole of the articular extremity will be torn off, and a nearly transverse line of fracture be produced (Figs. 9–18). If any part of the ligament gives way it will begin from the ulnar side of the middle fasciculus, and only that part of the bone whose attached fibres remain intact will be torn off, producing a very oblique line of fracture (Figs. 19–30), the obliquity running upward and outward from the articular surface to the outer margin of the bone; thus only a bit of the styloid process may be torn off (Figs. 19–22), or a triangular fragment involving the outer half or two-thirds of the articular surface (Figs. 23–30). The variations in the degree of tonicity and thickness of the ligamentous bands, and in the shape of the articular expansion of the base of the radius, and in the arrangement of its constituent bony lamellæ will in the nature of things always more or less modify the results of the avulsive force exercised by the strain on the anterior common ligament of the wrist.

Such experiments upon the cadaver are a more severe test than are the conditions afforded by a fall sustained by a living person, for in the tissues of the cadaver the tonicity of the soft parts present in life is absent and a certain degree of relaxation of the periarticular tissues is present, as the result of which the ligaments which are put under strain must stretch some and so lessen to that degree the power of the cross breaking strain that they transmit to the radius.

Similar experimental tests of the results of forced backward flexion (extension) of the hand in the living are, however, occasionally presented, *e.g.*, the case published by MacLeod in the *British Medical Journal* of July 12, 1879, p. 39. The case was this:

> A young man contended with an older and stronger man in a test of strength by placing elbows on a table, interlocking fingers, and then pressing back upon each other, palm to palm. The hand of the young man became violently extended until finally something gave way, with development of sharp pain in the radius and with the well-marked deformity characteristic of fracture of the inferior extremity of that bone.

Or as in another instance under my personal observation, a young woman, while standing on a chair, slipped and falling caught at a table to save herself. The fingers only of the outstretched hand reached the edge of the table, and the result of her effort was to have her hand bent strongly backward. Upon recovering herself she found her wrist was injured. When seen by me shortly afterward a fracture of the lower extremity of the radius was unmistakable.

Or as in this case: A young boy fourteen years of age, while endeavoring to prevent a boat from chafing against a dock, had his right forearm so caught between the boat and the dock that the boat impinged against his elbow while his hand was pressed against the dock. The hand was thus forced into extreme extension. I saw him within an hour after the injury. The right hand presented the characteristic silver fork deformity of fracture of the lower extremity of the radius, and examination revealed a transverse fracture about one-half an inch above the articular surface with backward displacement of the lower fragment.

Or as in the case of a boy of sixteen years, who, while assisting in lowering a box of tobacco down a staircase, had to support for a moment the whole weight of the case upon his extended hands as he attempted from below to prevent it from falling upon him. Immediately he realized that his left wrist had been injured. When I saw him upon the following day I found that the inferior extremity of the left radius was fractured, the line of fracture running transversely less than one-half inch above the articular edge; the lower fragment was slightly displaced backward.

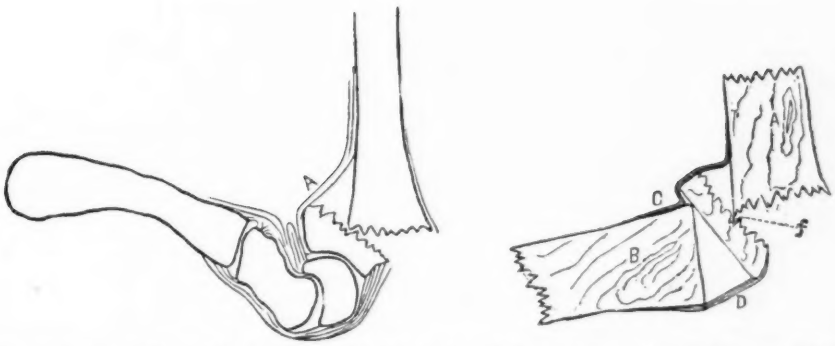
This group of experiences occurred within the space of a few months in 1879 and were recorded by me then. Since that time, however, the extensive use of motor-boats and of automobiles has furnished on a large scale a succession of experimental demonstrations of the effects of overextension of the hand in those frequent fractures of the lower extremity of the radius which have resulted simply from the sudden recoil or "kick back" of the crank of a gasoline explosion engine, by which the hand of the cranker is violently bent backward (Figs. 27 and 59).

The Force of Impact.—In the ordinary accidents resulting in a fracture of the base of the radius, other factors additional to that of avulsion enter. The most important of these is that remnant of the forward and downward impulse of the lower end of the radius, a force compounded of the weight of the body and the velocity of the fall which has been sustained, which remains after the force of avulsion, at first exercised by it, is expended.

When the lower fragment of the radius has been torn off it becomes virtually a part of the carpus with which it moves and by which it is carried backward (Figs. 31 and 32).

Forces of Cleavage.—(*A.*) ***Perpendicular wedge-like impact of the carpus against the articular cup of the base of the radius.*** It is conceivable that in the case of a sudden and violent fall the force of which is sustained by the hand, the rounded articular surface of the

FIG. 31. FIG. 32.



FIGS. 31 and 32.—Illustrating mechanism of the backward displacement of lower fragment of radius produced by resistance of wrist and hand resting upon the ground to force transmitted through forearm; periosteum (*A*) stripped up from back of upper fragment and still connecting the two fragments; impaction of upper into lower fragment probable; hand still in primary position of backward flexion.

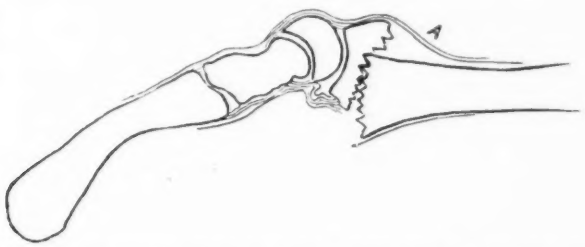


FIG. 33.—Diagram showing position of the parts at the wrist after fracture of the lower end of the radius, with displacement, upon return of hand to natural position. *A*, untorn periosteum.

FIG. 34.—Longitudinal fissure running upward from articular facet. Result of fall from top of a derrick. Ulnar aspect of specimen shown in Fig. 20.

FIG. 35.—Longitudinal fissure without transverse fracture. (Bigelow.)

FIG. 36.—Ulnar facet split off by longitudinal fissure. (N. Y. Hosp. Mus. No. 128.)

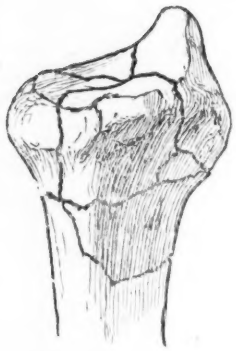


FIG. 37.—Multiple longitudinal fissures of base of radius, result of a fall while walking, in the person of a woman between fifty and sixty years of age. Death on sixth day from pulmonary œdema. No impaction of fragments at time of autopsy. (Personally communicated by Dr. Lewis A. Stimson. Letter May 26, 1881.)

FIG. 38.—Multiple longitudinal fissures of base of radius, from specimen loaned (July 16, 1879) by Dr. Frank H. Hamilton, and received by him from Dr. W. H. Van Buren. Anterior face. For condition of articular face see Fig. 41.

FIG. 39.—Oblique articular fracture complicated by longitudinal fissure through ulnar facet with lines of comminution visible within the carpal facet. Lateral view shows the line of transverse fracture, about half way through the thickness of the bone changes its direction to one running abruptly upwards for one inch, thus splitting away a mass from the posterior lip. This fragment is comminuted.

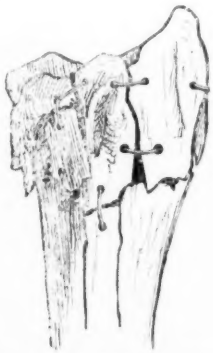


FIG. 40.—Multiple longitudinal fissures. Posterior face of Fig. 38.

FIG. 41.—Articular face of specimen shown in Figs. 38 and 40.

FIG. 42.—Showing dent in articular cup of radius from impact of carpus.

FIG. 43.

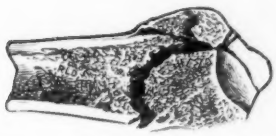


FIG. 45.—Showing manner in which the lower fragment may be split by the penetration into it from above of the upper fragment.

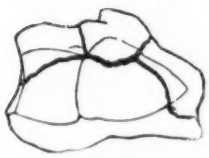


FIG. 44.

FIG. 46.—Lines of fissure in articular face of carpal cup of FIG. 45.

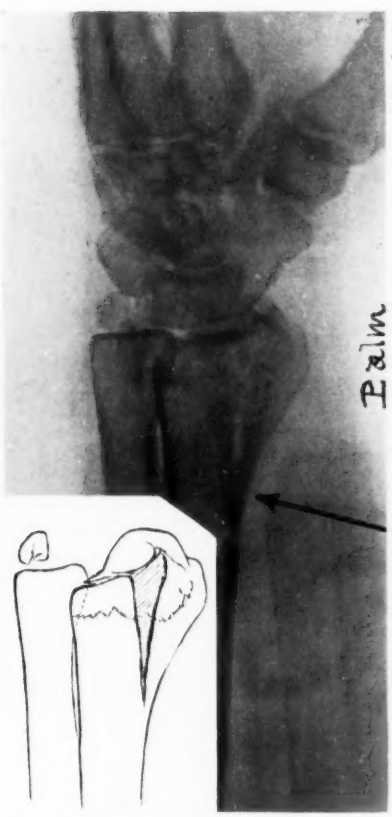


FIG. 47.—Longitudinal fissure from centre of carpal articular facet, running upwards for one inch, where it approaches the palmar surface of the radius (arrow). The lower part of this fragment is displaced forward but above the fragments are held together.

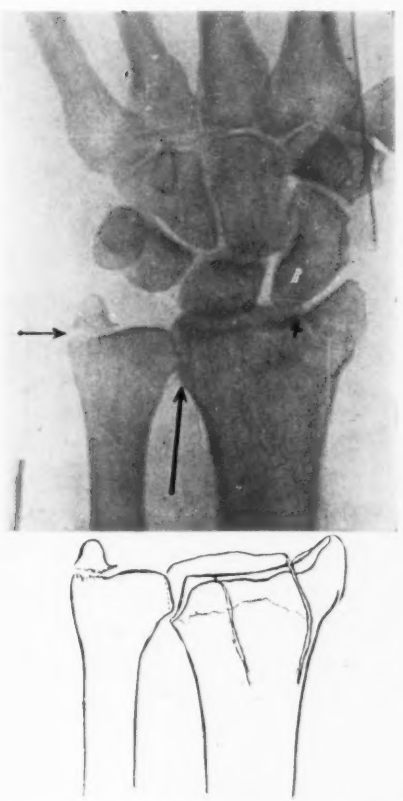


FIG. 48.—Longitudinal fracture (split) of the base of the radius. Line of split (x) visible running transversely along the carpal articular facet, continuing into a fissure running upwards through the ulnar facet (arrow). Ulnar styloid torn off.

FIG. 49.—Longitudinal fracture of the base of the radius (Rankin, *Long Island Med Jour.*, December, 1910).

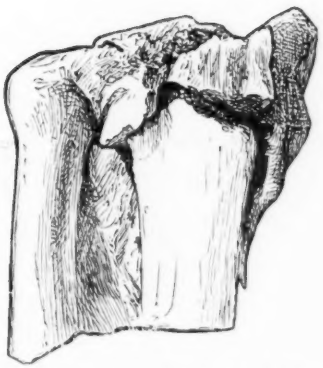


FIG. 50.—Transverse fracture with impaction of upper into lower fragment and comminution of lower fragment. The ulnar styloid is cracked off, but still held by its fibrous envelope. (Roosevelt Hosp. Mus. No. 189.)

FIG. 51.—Line of fracture from upper edge of ulnar facet transversely and obliquely outward and backward. Lower fragment comminuted. For lateral view see Fig. 73. (N.Y. Hosp. Mus. No. 120.)

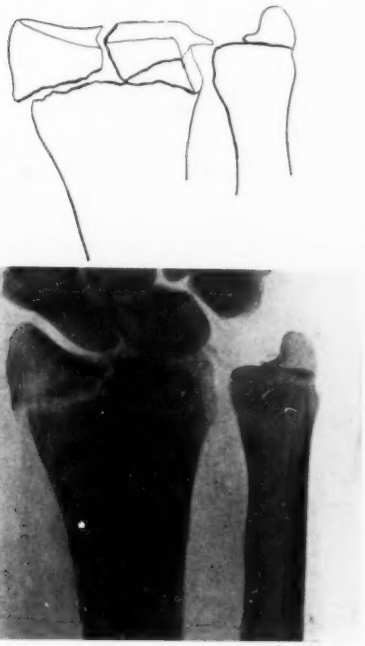


FIG. 52.—Lower fragment comminuted and displaced backwards two-thirds of its thickness as demonstrated in a lateral view. Ulnar styloid broken off.

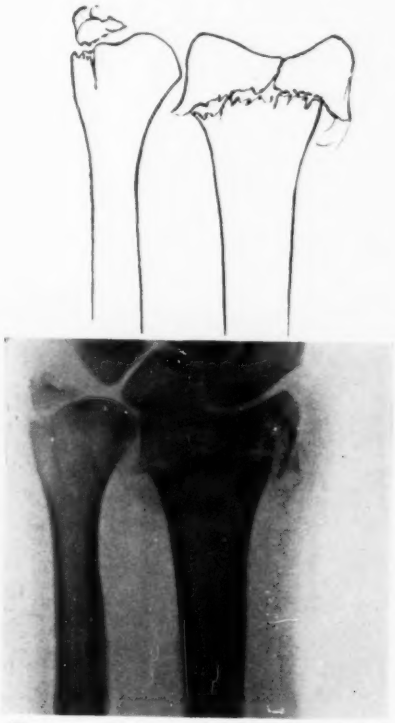


FIG. 53.—Transverse fracture three-eighths inch above carpal edge. Lower end of shaft fragment impacted into articular fragment. Ulnar styloid broken off.

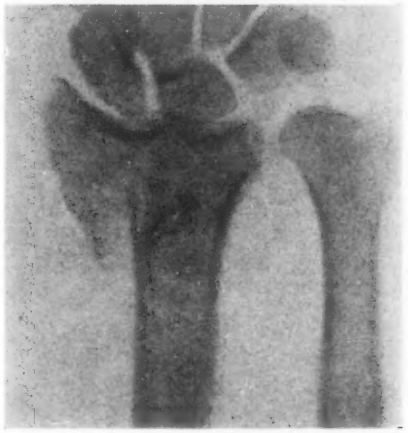


FIG. 54.—Lower end of upper fragment telescoped into lower; marked displacement outwards and backwards of the outer half of the radial articular facet and the styloid process, carrying the wrist and hand with it. Ulna torn from its radial connections.

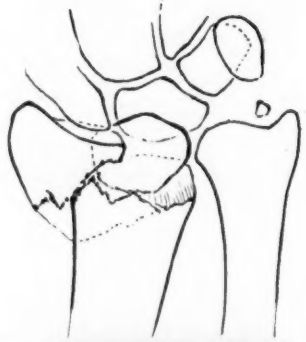


FIG. 55.—Upper fragment driven into lower fragment which is comminuted and carried backward and out. Abundant callus. Head of ulna forced down upon carpus; ulna styloid torn off.

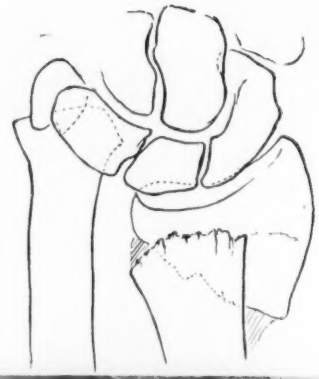


FIG. 56.—Extreme backward and outward displacement of lower fragment carrying carpus with it. Note callus filling in angle on outer side between lower and upper fragments. Upper fragment driven into lower; ulna torn away and thrust down on to the inner and posterior aspect of the carpus.

FIG. 57.—Backward and outward displacement with moderate impaction of upper fragment into lower.

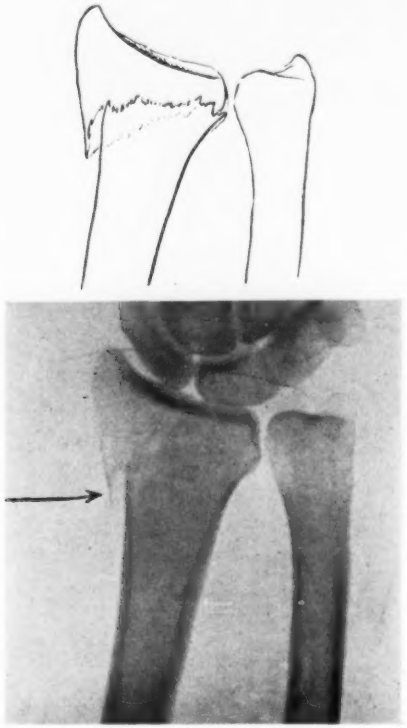


FIG. 58.—Lower end of upper fragment driven into lower fragment, most deeply on outer side; lower fragment displaced outwardly (arrow).

FIG. 59.—Man aged fifty-two years. Transverse fracture, three-fourths of an inch above carpal articular surface. Result of automobile crank kickback.

FIG. 60.—Man aged forty-five years. Transverse fracture, three-fourths of an inch above carpal articular surface, with backward and internal displacement of lower fragment which is comminuted by impaction into it of upper fragment; styloid process of ulna torn off. Head of ulna torn away from its attachment to the radius and thrust downward and outward. Fracture of scaphoid; result of a fall from a ladder. For lateral view see Fig. 95.

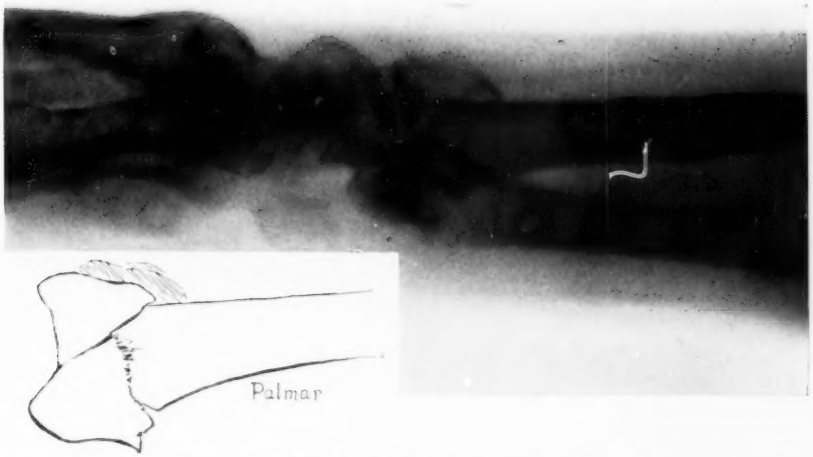


FIG. 61.—Lower fragment split by wedge-like impaction of end of upper fragment. Displacement forward by anterior portion and backward of dorsal portion of the split part. See Fig. 56.

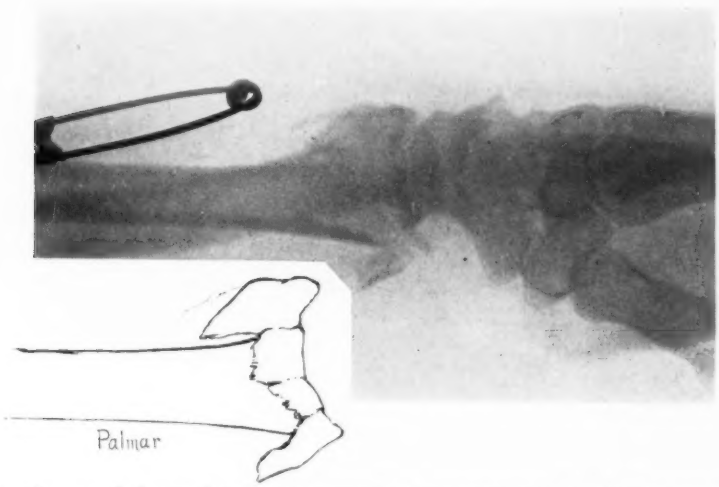


FIG. 62.—Lower end of upper fragment telescoped into lower fragment by splitting it and displacing the fragments backwards, forwards and outwards.

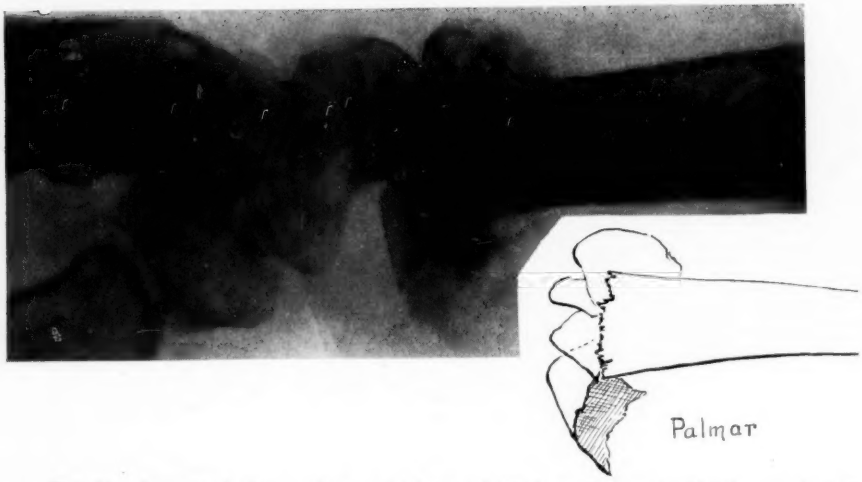


FIG. 63.—Lower end of upper fragment telescoped into lower fragment which is comminuted and mushroomed with fragments displaced both anteriorly and posteriorly. Compare with specimens shown in Figs. 62 and 64.

FIG. 64.—Upper fragment telescoped into lower; lower fragment split into many pieces, with anterior displacement of a portion.

carpal mass, before the movement of backward flexion is completed, may be driven up against the concave articular surface of the radius with such force as to split it or perforate it and cause stellate longitudinal lines of fracture in the radial base. As a matter of fact, that this does occur at times is proven by post-mortem dissections and in X-ray plates. The action of this force is seen very clearly in Figs. 34 to 49 given herewith, which are from dissected specimens or from X-ray photographs.

(*B.*) *Splitting of the lower fragment by descent into it of the lower end of the upper fragment.* More frequently, however, indeed very frequently, the lower fragment of the radius is split into fragments by the descent into it of the lower end of the upper fragment or shaft after the transverse lesion has been accomplished. This impaction of the upper fragment into the lower one is generally present when the momentum of the fall has been great, as in falls from a height, and the extent of the impaction is a fair index of the force which the elements of the wrist have had to sustain—the greater the space through which the fall has had its course the greater the velocity attained by which the weight of the body is to be multiplied in producing the resultant force. The friability of the particular bone involved also is a factor that modifies the result in any given case. Falls from a tree, from a ladder, from a second-story window, from a carriage, down a staircase—these are common conditions in which the outstretched hand receives the first brunt of a severe impact upon the ground of the falling body. In this class of cases the lower end of the radius is not only torn off, but as a part of the train of events, absolutely though infinitesimally later in point of time, the upper fragment, if the backward movement of the lower fragment has not been great enough to carry it clear of the broken surface of the upper fragment, is driven into the lower fragment and splits it into secondary fragments more or less numerous.

This splitting of the lower fragment by the descending upper fragment is well shown in Figs. 50 to 55 and 61 to 64. Most instructive also in this connection is a comparison of the two specimens shown, respectively, in Figs. 59 and 60. In both cases the subject was a powerful, large-boned man. Fig. 59 shows the effects of a simple forcible backward flexion at the wrist caused by an automobile crank kick back. The lower end of the radius has been torn off but the displacement has been very slight and there is no tendency to impaction. Fig. 60 shows the effect of a fall from a ladder at a height of ten feet or more above the ground. The lower end of the radius has not only been torn off, but the carpus has been carried markedly backward and outward (see also

Fig. 95 which gives a lateral view of the same case). The lower end of the upper fragment or shaft has been driven into the lower fragment and has split it. The head of the ulna has been torn from its attachment to the radius and has been forced downward and outward. Note particularly the difference in the relations of the ulna to the radius and carpus in the two cases. Finally, the styloid process of the ulna has been torn off.

Explosive Splitting of Lower Fragment of Radius.—In the course of the examination of numerous skiagraphs of injured wrists I have observed in certain more rare instances that the usual backward displacement of the upper fragment has not taken place before the denser cylinder of the upper fragment has been driven down into the cancellous tissue of the lower fragment with such force that the pieces into which the lower fragment has been split are driven off in various directions, to the palmar as well as to the dorsal sides. This necessarily causes marked shortening of the radius and outward protrusion of the head of the ulna. Figs. 61 to 64 are examples of this explosive splitting of the lower radial fragment.

Backward Displacement of the Lower Fragment of the Radius.—The usual, the typical displacement that characterizes the ordinary fracture of the lower extremity of the radius, is a movement toward the dorsum of the lower fragment. This is the chief cause of the deformity which proclaims the fracture (Figs. 65–68). The carpus as it is pressed upwards and backwards by the impact of the fall tends to carry with itself the fragment of the radius which has been torn off, and the extent to which such displacement may go is limited only by the resistance of the fibrous bindings that hold the parts together and the magnitude of the force that the fall has produced (see Figs. 31, 32, 33 and 68). Various degrees of this backward displacement are shown in Figs. 69 to 98, inclusive. In the bones shown in Figs. 76 and 77, the lower fragment is seen to have been torn from the shaft and moved downward and backward on its palmar side, while its posterior edge is still held by the periosteum as by a hinge. The result is an anterior gap in the radius which has later been filled with callus, and thus the plane of the carpal articular surface has been materially and permanently changed. The same condition of incomplete tearing away of a thin scale from the base of the radius, the fragments being still held together on the dorsum, is well shown in Figs. 81–83. In Fig. 80, *A, B, C,* an outline in red of a normal radius has been superimposed on the outline of the injured radius (Figs. 76, 77 and 79) to show this alteration in the plane of the carpal articular surface produced by the

FIG. 65.—Deformity of wrist due to fracture of the base of the radius with moderate backward displacement of the lower fragment.

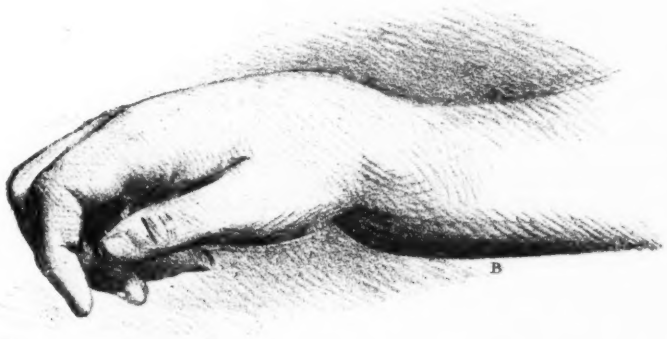


FIG. 66.—Typical silver-fork deformity caused by fracture of lower extremity of the radius, with moderate backward displacement of the lower fragment.

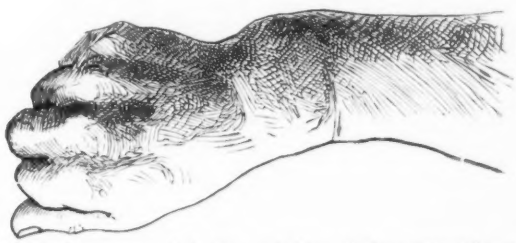


FIG. 67.—Showing bend of wrist to radial side, projection of ulna; external appearance of the wrist from which the specimen shown in Fig. 24 was obtained.

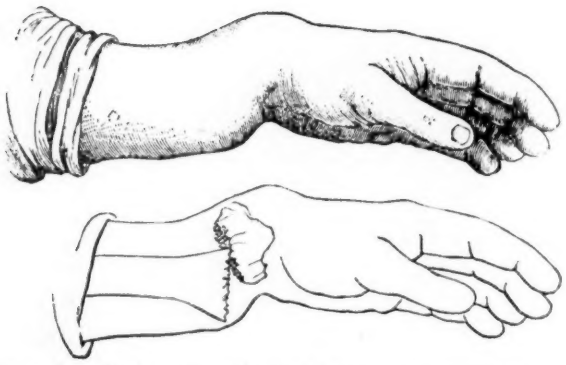


FIG. 68.—Diagram from Levis to show relations of bony displacement to external deformity.

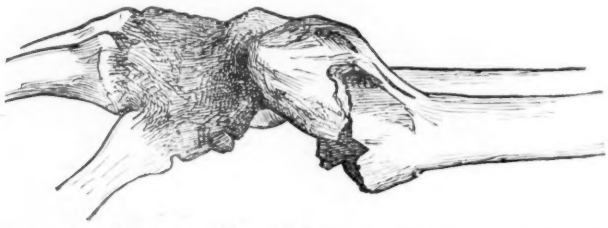


FIG. 69.—Note posterior displacement of lower fragment without impaction; stripped up periosteum still forms a band uniting the upper and lower fragments and holding them in their new relations.

FIG. 70.—Typical fracture by avulsion of the lower end of the radius with moderate degree of backward displacement of the lower fragment and slight impaction of upper into lower fragment; tip of styloid process of ulna torn off. Note angle on posterior aspect filled up with callus. Note sharp projection of the anterior edge of the upper fragment which irritated and disabled the palmar flexors.

FIG. 71.—Showing relations of elements of wrist-joint following backward displacement of torn-off fragment of radius; hand in position of forced dorsal flexion.

FIG. 72.—Demonstrates well the intact state of the posterior periosteum and fasciæ which is stripped up from the back of the shaft for an inch with backward tilting of the lower fragments.

FIG. 73.—Transverse fracture (see Fig. 51) with fragments separated in front, but held together behind by periosteum, resulting in backward tilting of the lower fragment. (N. Y. Hosp. Mus. No. 120.)

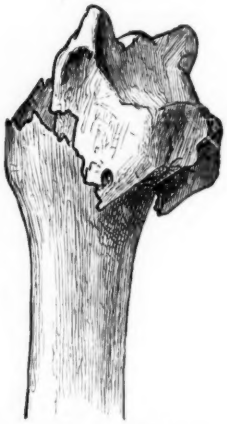


FIG. 74.—Complete detachment of lower fragment with marked backward displacement and tilting. Lower fragment entangled upon serrated posterior edge of upper fragment. (N. Y. Hosp. Mus. No. 123.)

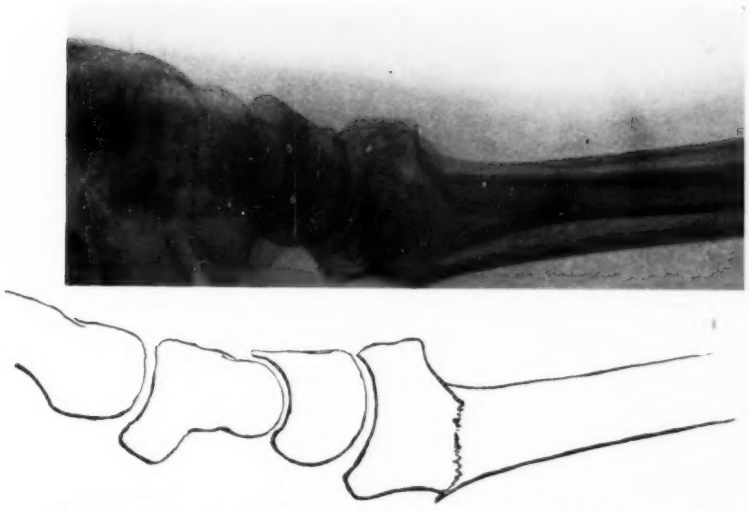


FIG. 75.—Transverse fracture of lower extremity of radius, backward displacement of the lower fragment, with impaction.

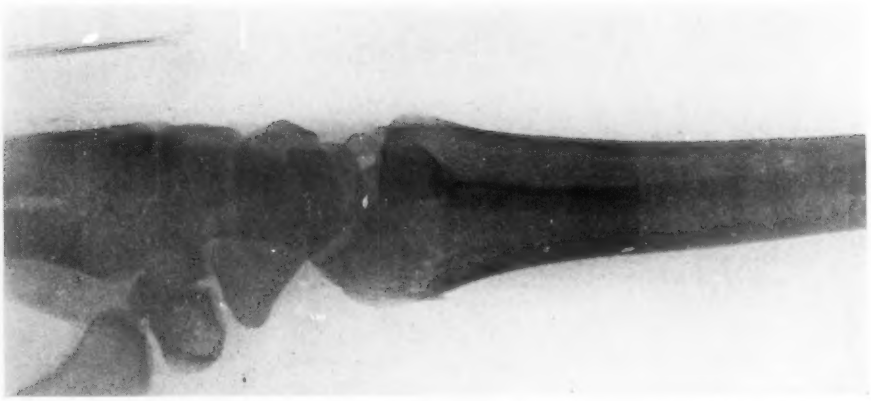


FIG. 76.—Lower fragment torn from upper in front but still attached behind by periosteum. Callus fills up the angle of separation in front. Note the alteration in the contour of the base of the radius and the changed plane of the carpal articular surface.

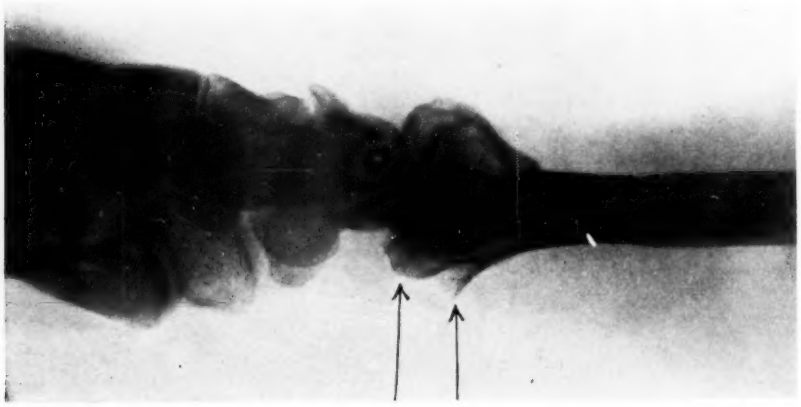


FIG. 77.—Line of separation anteriorly indicated by arrows; lower fragment displaced backwards and canted over and entangled upon posterior edge of upper fragment—slight impaction. Note mass of callus filling up angle behind.

FIG. 78.—Loss of anterior projection of palmar lip of articular surface of base of radius, result of fracture. (See Figs. 79 and 80.)

FIG. 79.—Old healed fracture of the base of the radius in which there has been backward bending of the lower fragment without displacement of the posterior bony lamellæ; the plane of the articular facet is changed (see Fig. 115); the lower palmar surface is flattened by the loss of the projection normal to the anterior articular lip (Fig. 114). The changed contour is suggestive of an original break similar to that shown in Fig. 70, *q.v.* Specimen obtained from a dissecting-room cadaver.

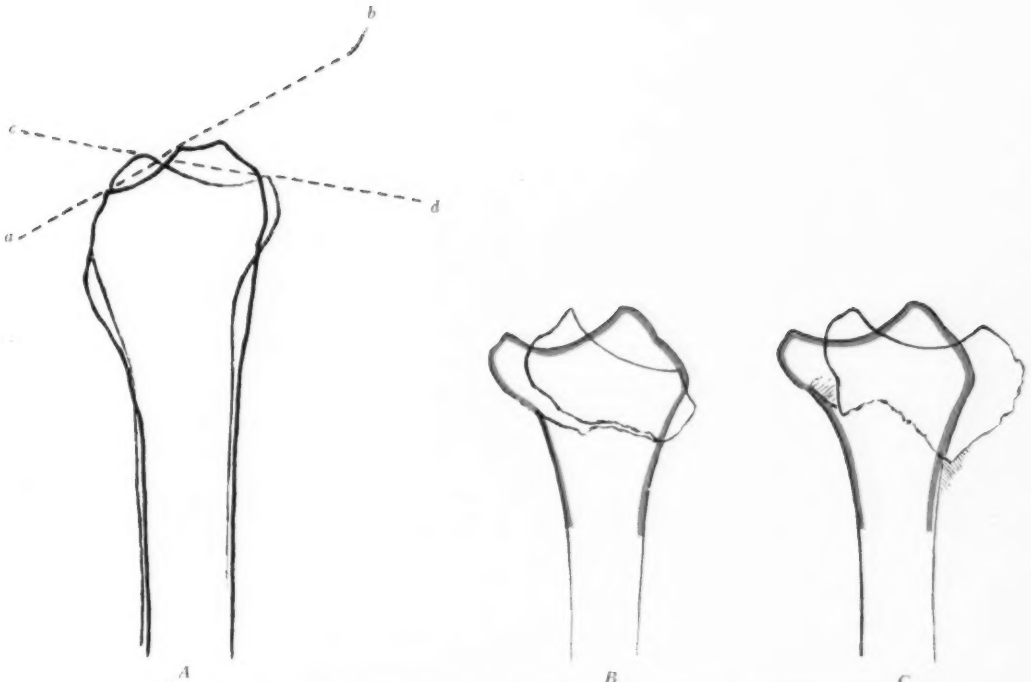


FIG. 80.—Outlines of the lower ends of fractured radii constructed from the specimens shown in Fig. 79 (*A*), Fig. 76 (*B*) and Fig. 77 (*C*). On these are superimposed outlines in red showing the normal contour of the base of the radius (see Fig. 1). In *A*, the dotted line *ab* indicates the plane of the articular surface of the injured bone; the line *cd*, that of the normal bone. The change in the plane of the carpal articular surface of the radius even in minor degrees of displacement is unmistakable.

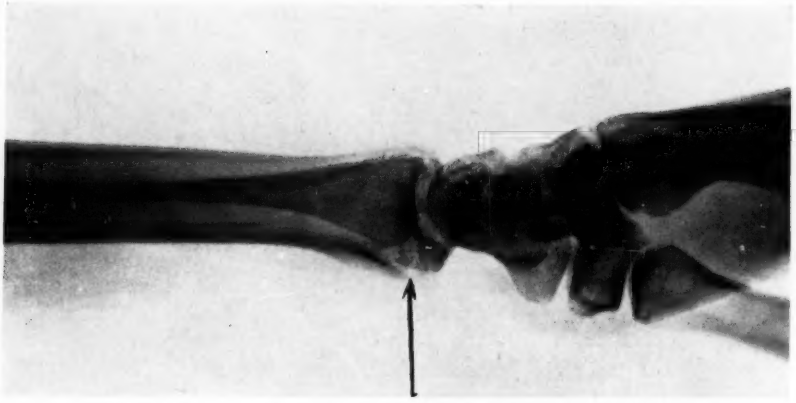


FIG. 81.—Incomplete fracture. Arrow-head points to line of fracture. Note the change from the normal of the plane of the carpal articular surface. Deformity negligible.

FIG. 82.—Fragments separated in front (arrow); moderate impaction of upper into lower fragment behind; no marked posterior displacement; plane of carpal articular surface changed.

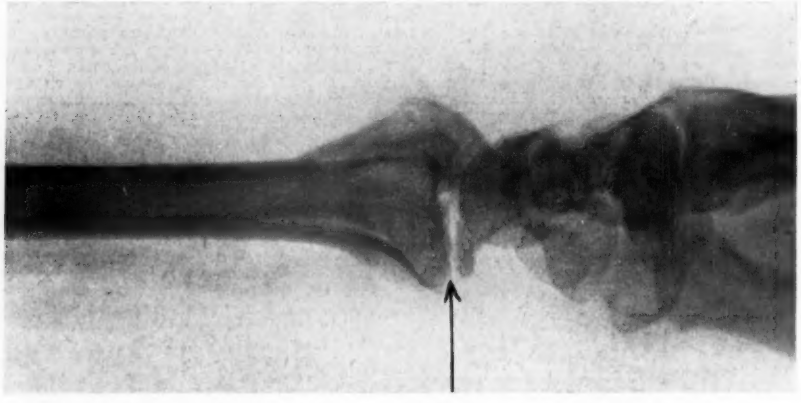


FIG. 83.—Anterior projection of radial articular lip preserved; line of fracture begins in the anterior edge of the articular lip and at a point half way to the back runs abruptly upward, splitting away a mass from the posterior lip of the radius. This fragment is comminuted.

FIG. 84.—Lower fragment displaced backwards with impaction into its substance of the lower end of the upper fragment. Note particularly the sliver of bone which suggests the tearing up of the posterior periosteum which covers it. Note the sharp line of separation anteriorly.

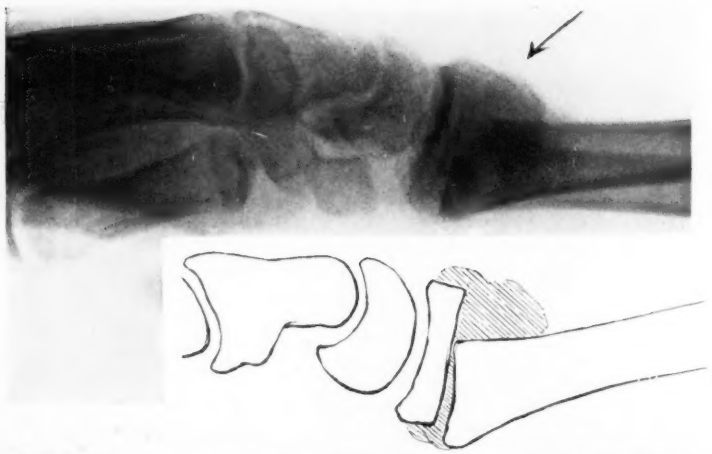


FIG. 85.—Epiphysial separation in a thirteen-year-old child: backward displacement of lower fragment; periosteum torn up and angle beneath periosteum filled with callus. See Fig. 109.

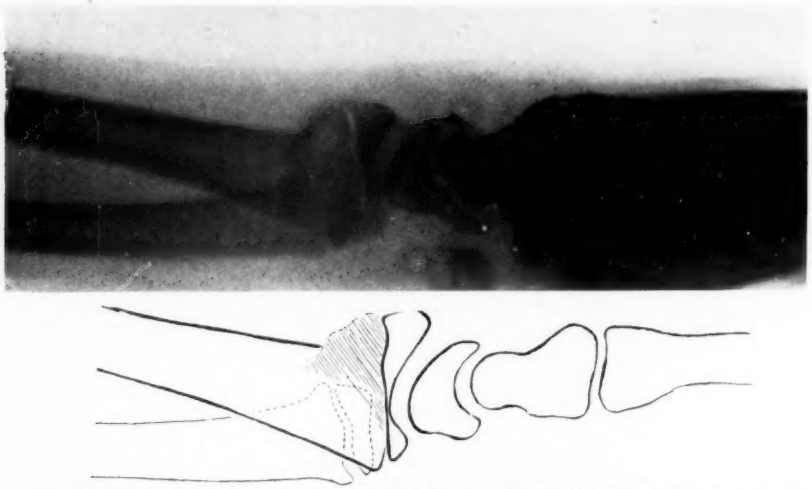


FIG. 86.—Epiphysis displaced backwards; angle on dorsum filled with callus. (Lateral view, see Fig. 106 for anteroposterior view.)

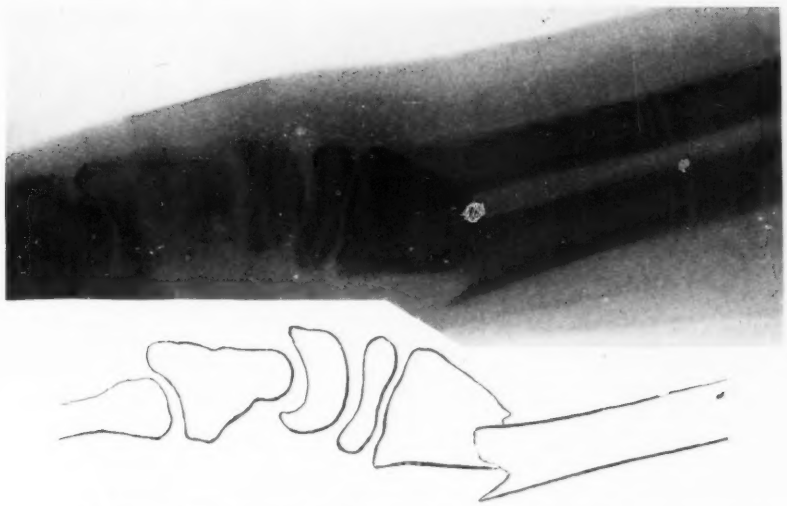


FIG. 87.—Fracture of radius seven-eighths of an inch above carpal articular surface (typical "Colles's fracture"). Lower fragment displaced backward and entangled on lower end of upper fragment.

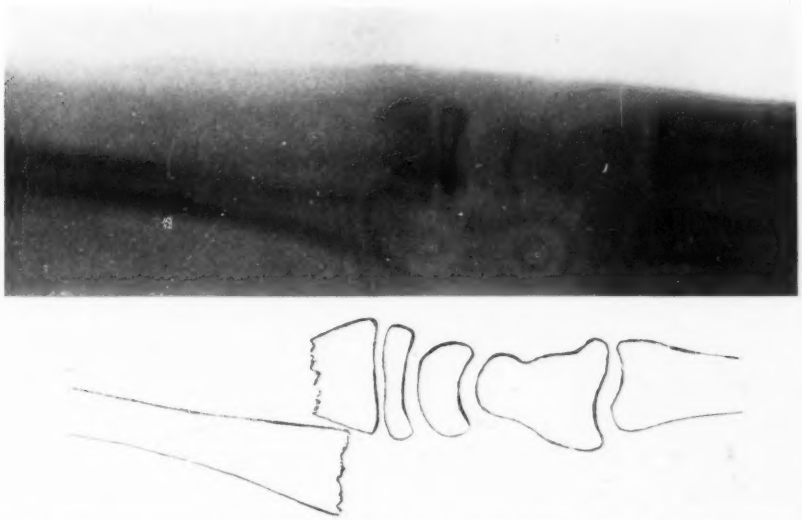


FIG. 88.—Extreme backward displacement of lower fragment, overriding the dorsum of lower end of upper fragment. Lateral of Fig. 96.

FIG. 89.—The broken-off lower fragment of the radius has been carried so far back that it lies entirely posterior to the upper fragment, the lower end of which it overrides (experimental fracture).

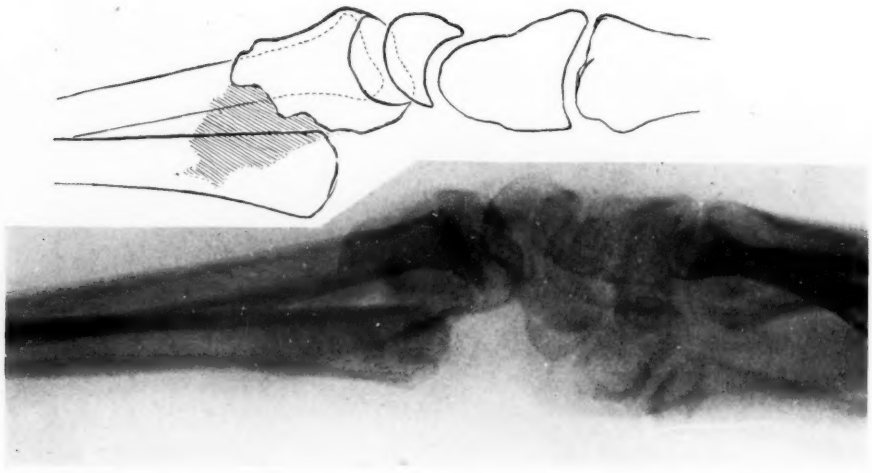


FIG. 90.—Extreme posterior displacement of lower fragment of radius, carrying with it the ulna and carpus. Lower end of upper fragment projects strongly in front. Lateral of Fig. 91.

FIG. 91.—Complete displacement backwards and outwards of lower fragment produced by playing hand ball six weeks after primary injury, in a youth of seventeen years. For lateral view see Fig. 90.

FIG. 92.—Extreme backward and outward displacement of lower fragment carrying carpus and hand. Ulna torn from its radial attachments and its head thrust down on the inner side of carpus. For lateral view see Fig. 94. Old injury.

FIG. 93.—Marked backward displacement of lower fragment; entanglement without impaction of lower on upper fragment. Note untorn periosteal bands.

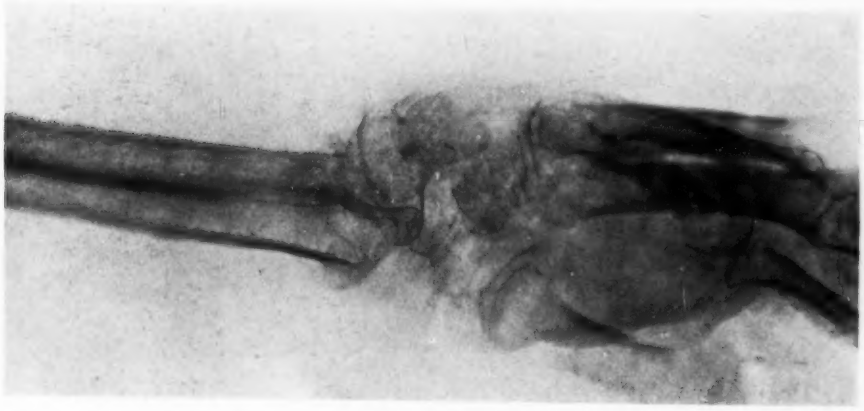


FIG. 94.—Extreme posterior displacement; skiagraph taken many years after the injury. Lateral of Fig. 92.

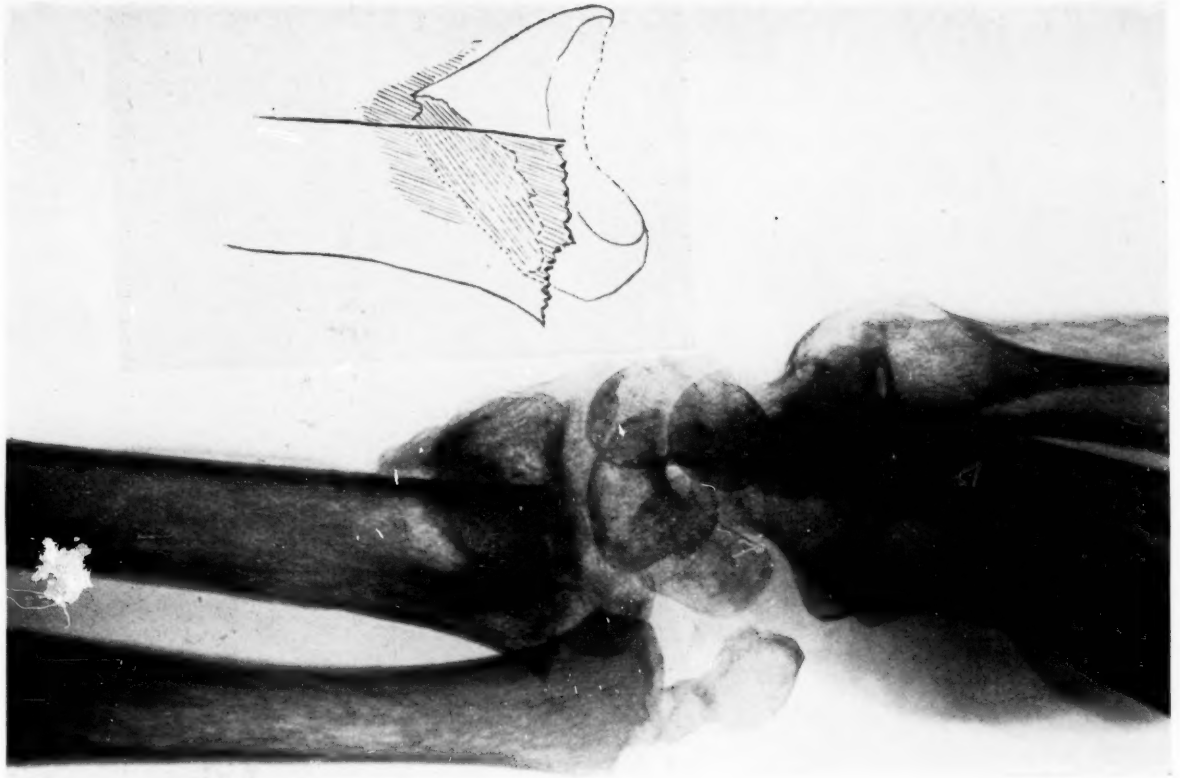


FIG. 95.—Obliquely lateral view of a wrist injured by a fall from a ladder. The lower fragment of the fractured radius is displaced backward and comminuted by the penetration into it of the lower end of the upper fragment. The head of the ulna is forced downward and forward, and its styloid process has been torn off. For anteroposterior view see Fig. 60.

injury. If one bears in mind the normal outline of the base of the radius (Fig. 1) the changes in its contour resulting from the ordinary fracture will readily be appreciated and the reason for the change will be understood and what can or cannot be done by treatment in the way of restoring the normal condition of the wrist may be demonstrated.

In the ordinary fracture, occasioned by a moderate force, the backward movement of the lower fragment is arrested before the fragment is carried to a plane entirely beyond that of the end of the shaft above. This is always the case where impaction of the one into the other is present. In many cases, however, this interlocking of the two fragments cannot properly be called an impaction, but is rather to be described as an entanglement of the irregular and serrated surfaces of the fracture masses into the irregularities one of the other. Figs. 69 to 87, inclusive, illustrate this lesser degree of displacement.

In Figs. 88 to 95 the most extreme degree of backward displacement is shown. The broken off lower fragment of the radius has been carried so far back that it lies entirely posterior to the upper fragment, the lower end of which it overrides. Such a degree of displacement, although not common, is by no means rare of occurrence. The case depicted in Figs. 90, 91 and 92 has this interesting and instructive history:

> A young man had sustained an injury to the wrist in the usual way without marked displacement; its full character was not appreciated and at the end of three weeks he had so far recovered that he ventured to indulge himself in a game of "hand-ball," a game in which the hand is continually thrown into violent extension in receiving and returning the ball. In the course of the game his injured wrist suddenly displayed an extreme degree of disability and deformity. A skiagraph then taken revealed the condition shown in the figures. It was evident that a fracture without displacement had taken place three weeks before and that now in the course of the repeated violent hyperextensions of the wrist called for in the playing of the game, the newly formed callus bond had given way and the final marked displacement had occurred.

Outward Displacement of Lower Fragment.—The immediate effect of the giving way of the radius and the backward slipping of the carpal fragment is a movement of rotation, in the direction of supination, of the carpal mass around the head of the ulna. Not infrequently the strain upon the carpo-ulnar ligamentous fibres (Fig. 4, *b*) is so great that the styloid process of the ulna is torn off (Figs. 24, 27,

47, 48, 52, 53, 56, 60, 70, 95, 104). The broken lower end of the shaft of the radius is thrust forward and the expanded lower articular fragment is made to appear to have moved laterally. This is seen very clearly in such Figs. as 54, 55, 56, 60, 89, 91, 92, 95, 96, 97, 98). There is undoubtedly some lateral movement but the chief element is the one of supinating rotation which brings the lower fragment into lateral relief. The lateral movement is also well shown in the specimen represented in Fig. 97, which is an old healed fracture found in a dissecting room subject. The slightest suggestion of it is visible in Fig. 59, a case in which there was a minimum displacement of the fragments.

I have, however, seen one case in which fourteen weeks after a fracture of the base of the radius had been manipulated by a surgeon in the effort to reduce the fracture the lower fragment was still on the dorsum of the upper one but had been displaced laterally toward the ulnar side, quite the opposite displacement to that usually present. I attributed the unusual character of the displacement to the hand having been kept strongly flexed laterally to the ulnar side while consolidation of the fracture was taking place, while at the same time the dorsal displacement was left unreduced. The styloid process of the ulna was torn off and the scaphoid bone fractured transversely at its middle. Much disability and pain still persisted. The accident was caused by an automobile crank kick-back.

Anterior Displacement of the Lower Fragment.—In falls upon the wrist with the hand in forward flexion it would seem theoretically possible that the lower end of the radius might be torn off, even as it is in the position of extension or backward flexion, although the mechanical conditions from the anatomical configuration of the lower end of the radius are much less favorable for the production of a force of avulsion. The rarity with which a fall is sustained by the hand with the wrist in flexion is so great that the occurrence of the accident in question is much less frequent than is the fracture with the wrist in extension.

As long ago as 1847, R. W. Smith, of Dublin, in his work on "Fractures in the Vicinity of Joints," p. 162, described this condition, based upon a case in which the lower end of the radius was broken and driven forward along with the carpus as the result of a violent fall upon the back of the hand. In 1896 this particular accident was made the subject of careful study by John B. Roberts, of Philadelphia, who collected a number of histories and described specimens in which the condition exists (*Transactions of Amer. Surgical Assn.*, 1896, xiv, 611).

FIG. 96.—The broken lower end of the shaft of the radius is thrust forwards and the lower articular fragment in backward rotation is made to appear to have moved laterally.

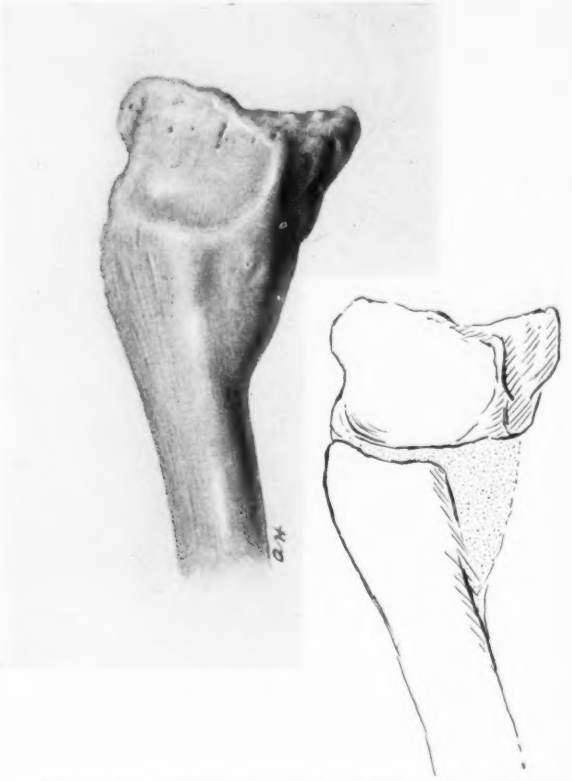


FIG. 97.—Repair after fracture of the base of the radius with unreduced backward and outward displacement of the lower fragment. From a specimen found in a dissecting-room cadaver. To illustrate especially the tendency to outward displacement of the lower fragment.

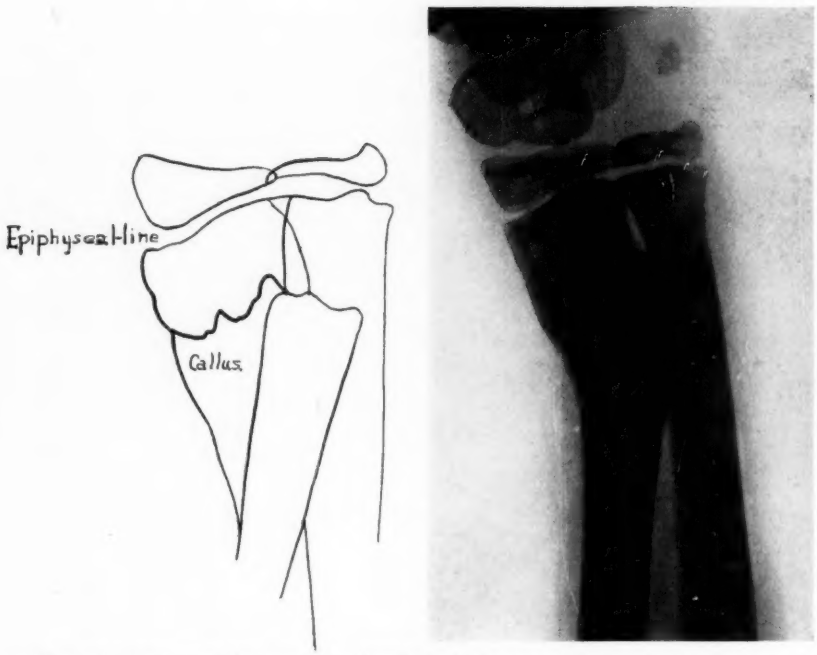


FIG. 98.—Transverse fracture three-fourths inch above articular surface in a youth. Lower fragment carried strongly outwards and backwards; no impaction; periosteum stripped up and angle filled with callus. See Fig. 85.

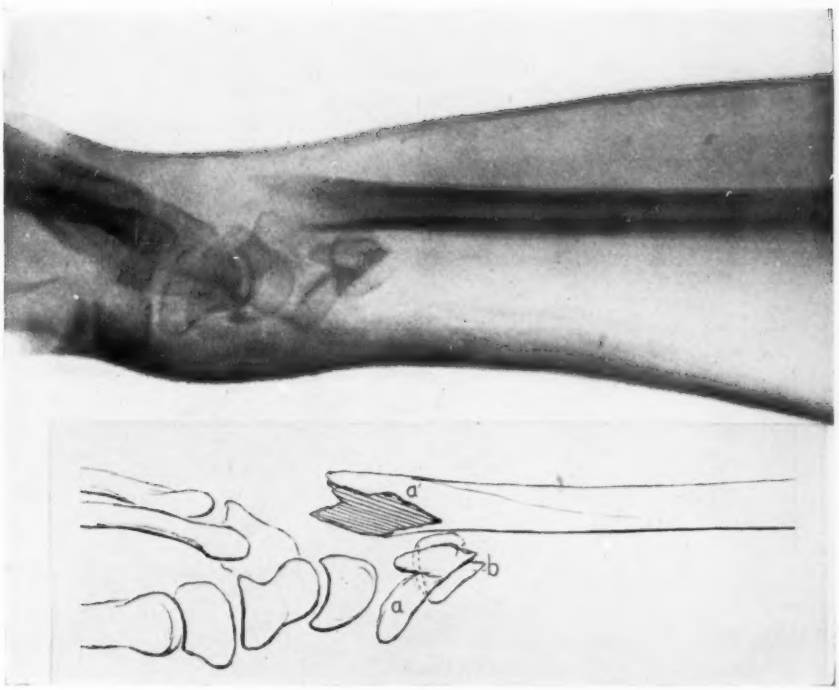


FIG. 99.—Fracture of the lower end of the radius and ulna with anterior displacement of the lower fragments. *a*, lower fragment of the radius; *a'*, fracture surface of lower end of shaft of radius; *b*, lower fragment of ulna. (Hitzrot, ANNALS OF SURGERY, June, 1915.)

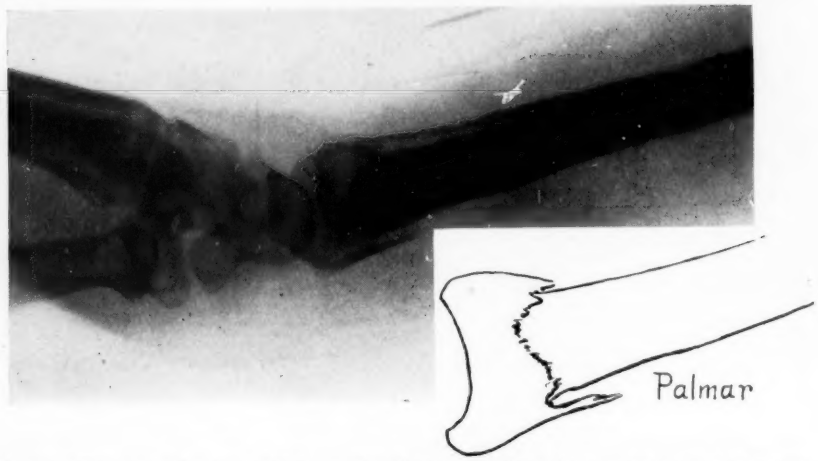


FIG. 100.—Transverse fracture with impaction of upper into lower fragment; fragment of articular segment displaced forward.

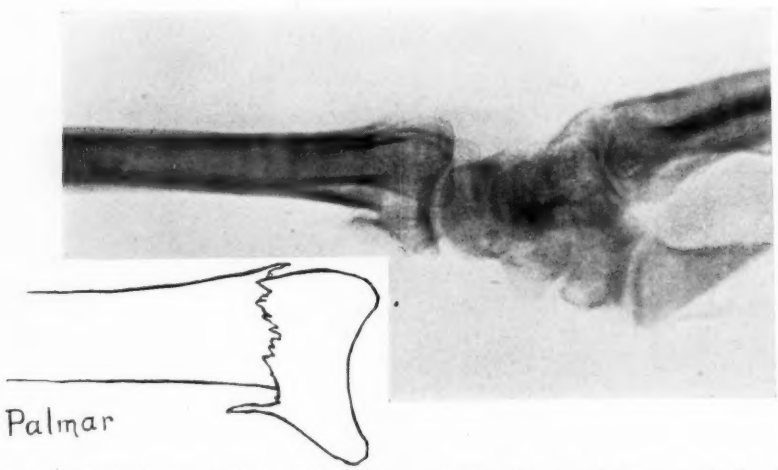


FIG. 101.—Lower fragment displaced forward, exaggerating the normal palmar projection of the anterior lip.

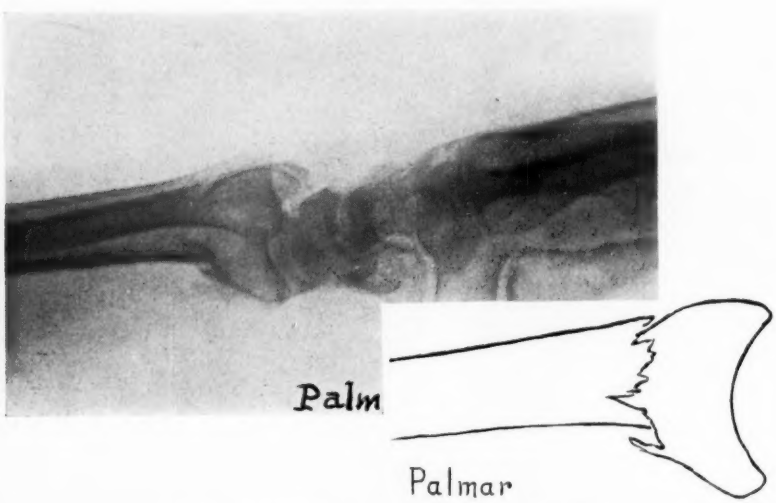


FIG. 102.—Anterior displacement of lower fragment.

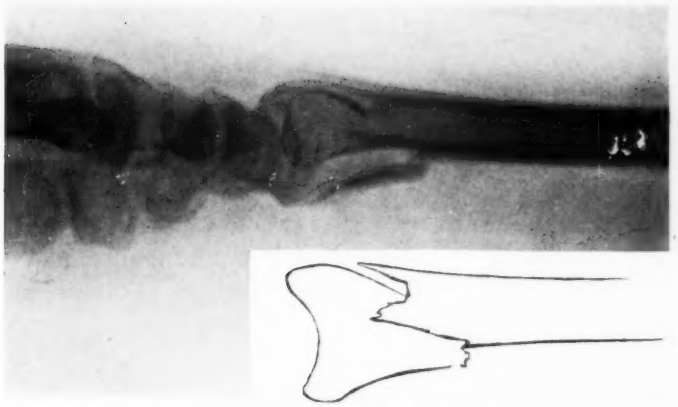


FIG. 103.—Anterior portion of lower fragment displaced *forward*. (Seibert.) See anteroposterior view, Fig. 104.

FIG. 104.—Lower fragment displaced forward; slight impaction of upper into lower fragment. Styloid process of ulna broken off.

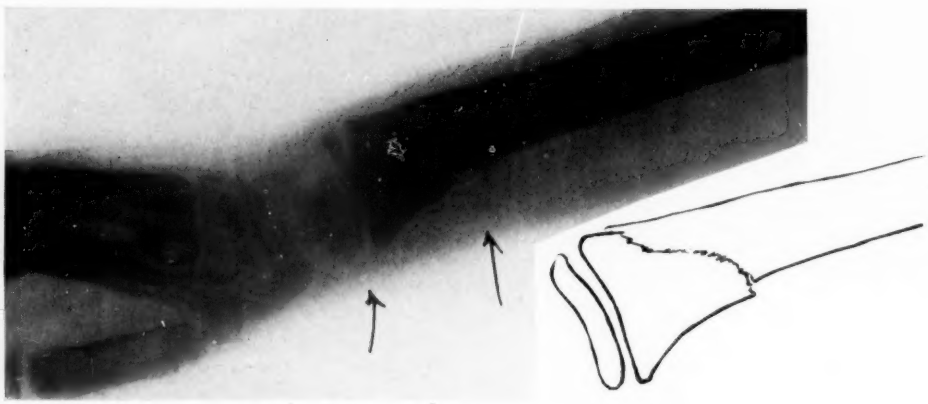


FIG. 105.—Oblique fracture in anteroposterior line of lower end of radius in a child seven years of age. One arrow points to the epiphysial line, one to the line of fracture.

In 1904, Dr. Francis T. Stewart, of Philadelphia, reported to the Academy of Surgery of that city the case of a man fifty years of age who had received a fracture of the lower end of the radius from the blow of a heavy weapon upon the back of the wrist. Skiagrams showed the lower fragment displaced to the palmar side. Dr. John B. Roberts at the same time described the case of a woman who had been thrown from a horse and struck on the back of her hand. The lower extremity of the radius was fractured and the lower fragment was driven forward (ANNALS OF SURGERY, 1904, xl, 423).

In 1915, Dr. J. M. Hitzrot, of New York, reported to the New York Surgical Society (ANNALS OF SURGERY, 1915, lxi, 740) a similar case. A woman was thrown from a horse and fell with her left hand flexed under her. Together with other injuries the lower ends of the radius and the ulna were fractured and the lower fragments were displaced forward and outward to the radial side. The lower projecting ends of the upper fragments could be plainly seen and palpated on the back of the wrist. Skiagraph (Fig. 99) shows the lower fragments of both radius and ulna completely displaced forward and driven upward along the palmar surface of the radius. Traction and manipulation failed to correct the position, whereupon the parts were exposed by an incision on the dorsum, when it was found that the lower end of the upper radial fragment had perforated the annular ligament by the fibres of which it was held and the whole mass of the extensor tendons had dropped between the fragments. After operative readjustment of these structures had been effected, the proper apposition of the bone ends was readily made and a final ideal repair secured.

Among the cases which are the subject of the present study a number have already been figured (Figs. 61–64) in which anterior displacement of some of the comminuted pieces of the fragment, riven by the descent into it of the end of the upper fragment, is present.

In Figs. 101 to 105 are presented other examples in which the articular segment is displaced forward. In the case which is the subject of Fig. 47 the anterior lip of the carpal articular surface has been split off by a longitudinal line of fission which exaggerates the normal palmar projection of that part of the radius. These cases, however, together with the similar ones already noted on page 8, belong to quite a different class from those with anterior displacement considered by Smith and Roberts, and from the case of Hitzrot shown in Fig. 99. In the latter class we have to do with a distinct forward movement *en masse* of the fragment.

When one considers the histories of the cases in which such anterior displacement of the lower fragment has been found it is evident that they are the results of direct violence applied to the dorsum of the lower end of the radius rather than of any such indirect force as that which plays so large a part in the causation of the ordinary fracture occurring during extension of the wrist.

In Figs. 103 to 105 the condition of the lower end of the radius speaks plainly for a blow directly upon the dorsum of the articular expansion of the bone, breaking it off and driving it forward. This particular condition shown in Figs. 103 and 104 occurred in the person of a heavy woman, thirty years of age, who fell in alighting from a trolley car. Presumably she put out her hands to break her fall. No positive statement as to the exact manner in which the wrist came in contact with the pavement can be given by her.

The displacement shown in Fig. 105 is quite similar to that in Fig. 103. The obliquity of the line of fracture running upward and forward and the slight forward slide of the lower fragment speak positively for it to have been caused by a force from the dorsum. It occurred in the person of a child, seven years of age, who tripped while running over a boardwalk and fell violently forward.

Epiphysial Separations.—In children and adolescents, up to the age when the conjugate epiphysial cartilage becomes ossified—nineteenth to twentieth year—the result of a cross-breaking strain upon the lower end of the radius may be that the fragment that is torn off is composed practically of the epiphysis only (Figs. 85, 86, 106, 107, 108, 109). Owing to the relatively small size of the bony nucleus of the epiphysis during early childhood the base of the radius during this period partakes of the tough and elastic characteristics of the predominating cartilage rather than of the friability and density of bone. After the age of twelve the osseous development of the epiphysis has advanced so far as to materially alter its physical nature. The cases of epiphysial separation recorded are practically limited to the years between twelve and twenty. The separation, however, seldom, if ever, occurs through the substance of the cartilage but rather through the spongy, osseous tissue which immediately adjoins it (Ollier), a certain amount of which always clings to the cartilage. Not infrequently the fracture plane, which has begun along the epiphysial line in front, passes into the substance of the diaphysis as the posterior surface of the radius is approached by the fracture line (Fig. 109). Epiphysial separations are comparatively infrequent because the elasticity and resiliency of the osseo-cartilaginous tissues of childhood lessen the tendency to any fracture at the wrist, notwithstanding the frequent falls that are characteristic of the heedless activity of childhood. A child's fall, broken by the outstretched hand, more frequently eventuates in a fracture of the forearm or in a dislocation at the elbow than in a fracture through the lower end of the radius. The bone may give way through the shaft at a point but little above the epiphysial line, without any

involvement of the epiphysial conjugate cartilage. Such a condition is presented in Figs. 87, 88, 98, 105.

Arrest of growth of the radius from premature ossification of the lower epiphysial conjugate cartilage, the result of the traumatism of a fracture, may result, but is rare. Of 100 cases of traumatic epiphysial separation of various bones, collected by von Bruns, in 13 only was growth arrested; eight of these were of the lower epiphysis of the radius. Fig. 110 shows the condition produced by lack of development in length at the base of the radius after a fracture through the epiphysis sustained at the age of twelve years. The normal growth of the ulna has made its lower end to become very prominent on the ulnar side of the wrist, while the carpus, bound more strongly and extensively to the radius, is left behind and pushed over to the radial side of the wrist. There is no suggestion of shortening of the radius from unreduced overlapping of the fragments of the original injury. This wrist was seen by the writer immediately after the original accident; the backward displacement of the lower fragment was very marked; it was reduced without difficulty, and the subsequent course of repair was without accident. Twenty years later, the boy having become a man thirty-two years old, an opportunity occurred to examine the wrist, and the condition as shown in the figure was found present. A plaster cast was taken of it, from which the photograph reproduced in Fig. 110 was taken. The function of the wrist has not been impaired.

Poland (" Traumatic Separation of the Epiphyses," p. 564) says that there are several specimens in the museums of London hospitals which show great dwarfing of the radius and deformity of the forearm after what was probably an epiphysial separation. He reports also a number of clinical cases in which arrest of growth of the radius followed such epiphysial separation. Great or complete displacement of the epiphysis, as in the case of my own patient, must usually have taken place to supply the conditions requisite for arrest of growth at the base of the radius, which is due to the premature ossification of the conjugate cartilage during the process of repair. Such premature excess of ossification occurs more especially in comminuted fractures which involve the extremity of the diaphysis as well as the epiphysis. But in some of the recorded cases of arrest of growth after epiphysial injuries there has been no displacement and in some but little local injury.

Authors in treating of wrist injuries in childhood, and surgeons in undertaking the treatment of such cases, ought to be very explicit to state the possibilities of later deformities appearing as the result of develop-

mental changes, over which the surgeon has no control, and for which he may in no degree be responsible or deserving of reproach.

Dorsal Untorn Periosteum.—The peculiar elements which determine the usual fracture of the radius *par arrachement* are such that as the lower fragment is torn away from the rest of the bone and slips backwards, it tends to strip up from the adjacent dorsal surface of the shaft of the radius more or less of the dense, loosely adherent periosteum which enwraps this part of the bone. The dorsal periosteum further is so closely blended with the fibrous tissue of the tendon sheaths which lie over it that the combined mass constitutes a thick strong fibrous envelope to the parts enclosed within it. This has been repeatedly referred to in previous paragraphs and is well shown in many of the figures already presented to illustrate other phases of this injury—see especially Figs. 31, 32, 33, 69, 72, 73, 89, 93, 96.

This untorn portion of the dorsal periosteum becomes a sort of ligament which continues to connect the two fragments, and exercises some control over their relations to each other, and also remains as a determining factor in the extent and position of the callus which is formed to weld them together again.

As soon as the extending force is withdrawn and the hand again falls into forward flexion, this pseudo-ligament is made tense (see Fig. 33) and in its tension binds in its faulty position the lower fragment in whatever degree of entanglement with or impalement upon the lower end of the upper fragment it may have sustained. This effect is well shown in Figs. 69 and 89. This band forms a real obstacle of some importance to the disentanglement of the fragments or to the breaking up of any impaction if it exists. To break up such impaction or to disentangle an overriding fragment is necessarily the first step to be taken in any effort of reduction. The appreciation of the presence and effect of this band gives an important hint as to the first manipulative step to resort to when reduction is undertaken. To facilitate the drawing apart of the broken surfaces this band must be relaxed. Such desired relaxation is at once secured by putting the hand again in full dorsal flexion (Fig. 31).

As long as the return of the lower fragment to its normal relation with the upper fragment is imperfect a space is left between the stripped up periosteum and the compact layer of the denuded bone. This space fills with blood clot to be later replaced by callus which solidifies duly into bone. The amount of this new formed bone and its contour is quite accurately outlined by the periosteum that contains it. This formation of new bone underneath the periosteal bridge did not escape the notice

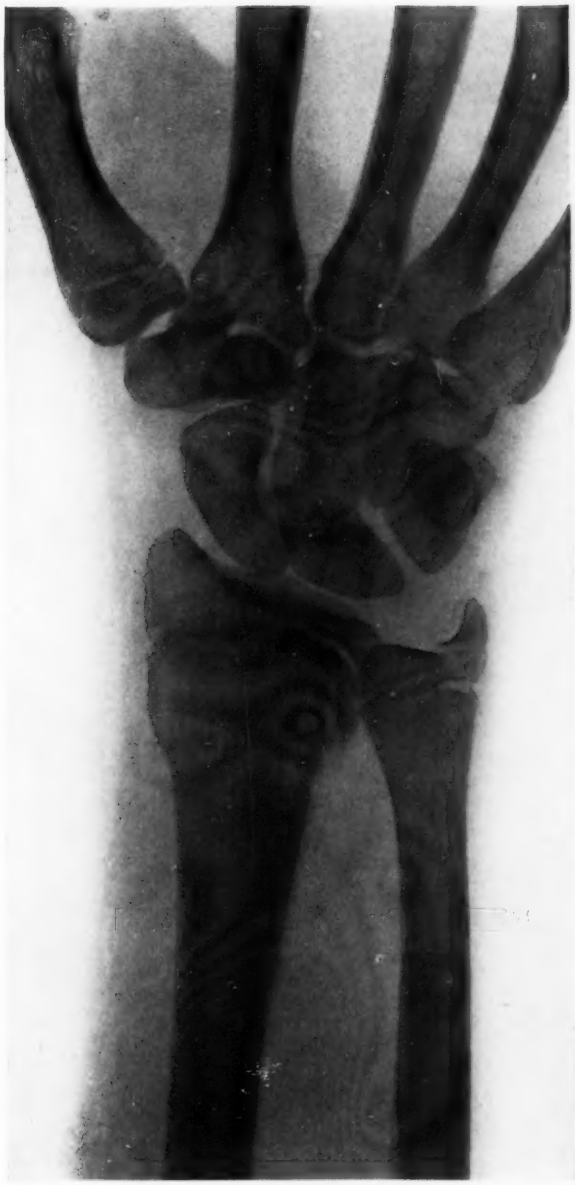


FIG. 106.—Separation of epiphysis with backward displacement. Lateral view (Fig. 86) shows moderate backward displacement of the radial epiphysis making an angle with the dorsum of the lower end of the upper fragment which is filled with callus.

FIG. 107.—A lateral view of this case shows slight backward displacement of the epiphysis with line of fracture extending near posterior surface upwards into the substance of the diaphysis.

FIG. 108.—Lateral view shows the epiphysis torn off and displaced backwards for half the thickness of the bone.

FIG. 109.—Epiphysial separation with backward displacement of the epiphysis—child of thirteen years. Dorsal angle filled with abundant callus. See Fig. 85.

FIG. 110.—Deformity from obliteration of lower epiphysial cartilage of radius, following fracture of the base of the radius in a boy of twelve years; fragments put in good place and healed without deformity at the time. Gradual development of the condition shown in photograph with the growth to manhood of the boy; cast taken at age of thirty-two. Radius relatively short from lack of development in length; ulna prominent; hand inclined to radial side.

FIG. 111.

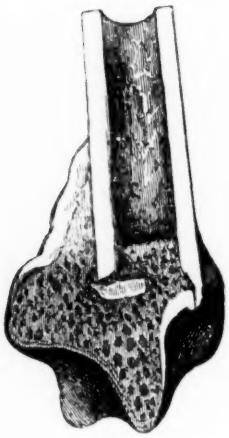


FIG. 112.

FIG. 113.—Sagittal section of old fractures of the lower extremity of the radius, healed in deformity, to show the results of the stripping up of the periosteum from the dorsum of the shaft; the subperiosteal space produced has been filled with callus which by its ossification mimics penetration of the cancellous lower end of the bone by the compact tissue of the shaft above. From Robert William Smith's Treatise on Fractures in the Vicinity of Joints, 1850, pp. 148, 149, 152 and 154.

FIG. 114.

of earlier writers on this fracture, although misinterpreted by some as an evidence of impaction. Figs. 111 to 114 are the familiar illustrations from Robert William Smith's "Treatise on Fractures in the Vicinity of Joints," Dublin, 1847. They show sagittal sections of old fractures of the lower extremity of the radius healed in deformity. It is to be noted that the defect left on the palmar side by the backward slipping of the lower fragment, where the periosteum was torn cleanly across, has not been filled up, but the end of the upper fragment continues to project sharply,—see especially Figs. 113 and 114. Posteriorly, however, where the periosteum has been stripped up as described, abundant new bone has been laid down, reaching some distance upwards along the dorsum of the radius and enclosing deeply the cancellated cylinder that is here present. Figs. 97 and 98 show the result of the same source of new bone formation.

Incomplete Fractures.—That the lower end of the radius is frequently torn off but partially on account of the feebleness of the avulsive force, or because of there being in the particular bone an unusual degree of strength to resist such force is to be expected if we are correct in the description of the mechanism whereby the more serious injuries are produced.

The longitudinal splits and the radiating fissures of the articular facet of the base of the radius (Figs. 35, 42, 47, 48, 49), are included in this class, and also those many cases in which the lower fragment is torn off, but not displaced backward, being still held by the periosteal hinge on the dorsum (Figs. 115, 116, 117). This is ideally shown in the experimental fracture shown in Fig. 9. It is the condition in the specimens from which skiagraphs 11, 12, 28, 30, and 73 have been taken. When the force of extension is suspended in such cases the fragments spontaneously resume their proper relations to each other and no deformity follows. Under rest repair rapidly takes place. The injury is classed simply as a sprained wrist unless a skiagram is taken and the real lesion demonstrated.

Fracture of the Ulnar Styloid Process.—Reference to many of the preceding illustrations (Figs. 12, 24, 27, 47, 48, 52, 53, 55, 60, 70, 95, 99, 104), which present skiagrams of recent fractures, shows in each that the styloid process of the ulna has been torn off, in addition to the injury to the radius. This injury to the ulna is a very frequent one, and is almost inevitable when there has been much backward displacement and rotation outwards of the articular fragment of the radius. The mechanism of its production has been described on page 9. The carpo-ulnar fibres, of the anterior common ligament (Fig. 2b), sustain

most of the cross-breaking strain after the articular base of the radius has given way, and the tendency is to tear off the styloid process into which these fibres are inserted, a result which in fact frequently follows. In extreme degrees of violence the jagged end of the broken ulna may be forced through the skin. The student of the literature of fractures will remember the laconic but comprehensive account given by Sir Astley Cooper, in his "Treatise on Dislocations and Fractures of the Joints" (7th ed., p. 378), of such a case, under date of June 21, 1818: "John Winter fell from a ladder on his hand and knee; the hand was bent back, and the ulna protruded at the inner part of the wrist. Mr. Steel, of Berkhampstead, attended; the bone was reduced, a roller was put around the wrist, and the wound healed very soon by adhesion."

Associated Fracture of the Carpal Bones.—That the carpal bones are not frequently fractured or dislocated as the result of violence sustained by the wrist is due not only to the protection which they receive from the dense and strong fibrous ligamentous and tendinous structures by which they are invested (see Figs. 1, 2, 4), aided by the tonicity of the muscular masses by which these tendons are controlled, but also by the powerful manner in which the most frequent forces of extreme flexion backwards or forwards are transmitted upwards to the base of the radius. In this connection those injuries are not considered which are caused by direct force, as a blow or a crush. As, however, one values the strength of the disruptive force which the scaphoid and semilunar bones especially must sustain in the course of such a traumatism as is present in a forced hyperextension one is sure that in occasional instances these bones of the carpus will be fractured or forced out of their position at the same time that the radius is fractured, and that in some instances the chief lesion will be sustained by them,—the greater the force and the more resistant the lower end of the radius the more positive the effect upon the adjacent bones of the carpus. Thirty-five years ago I had the opportunity of dissecting the wrist shown in Fig. 24 which had been injured by a fall from a height of 20 feet to the ground. The sketch was made at the time the dissection was done. In this wrist I found that not only had the styloid processes of the radius and of the ulna been torn away but that the semilunar bone had been fractured transversely as shown in the drawing. Similar injuries both of the semilunar and of the scaphoid were occasionally detected by me in the course of many experiments made on the cadaver as to the results of overextension of the wrist when associated with force applied from above and transmitted through the bones of the forearm to the wrist. In 1905 Codman and Amory (ANNALS OF SURGERY, xli, 321)

Fig. 115.

Fig. 116.

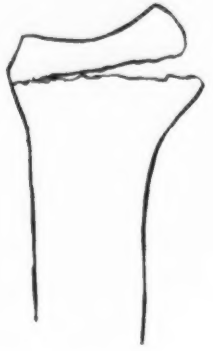
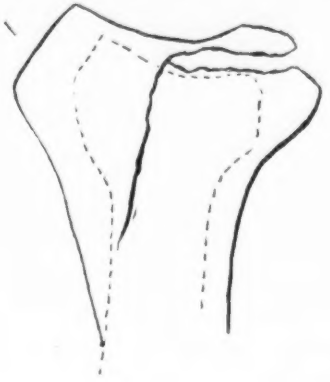


Fig. 117.



Figs. 115, 116 and 117.—Incomplete fracture of the base of the radius. Diagrams constructed from skiagraphs.

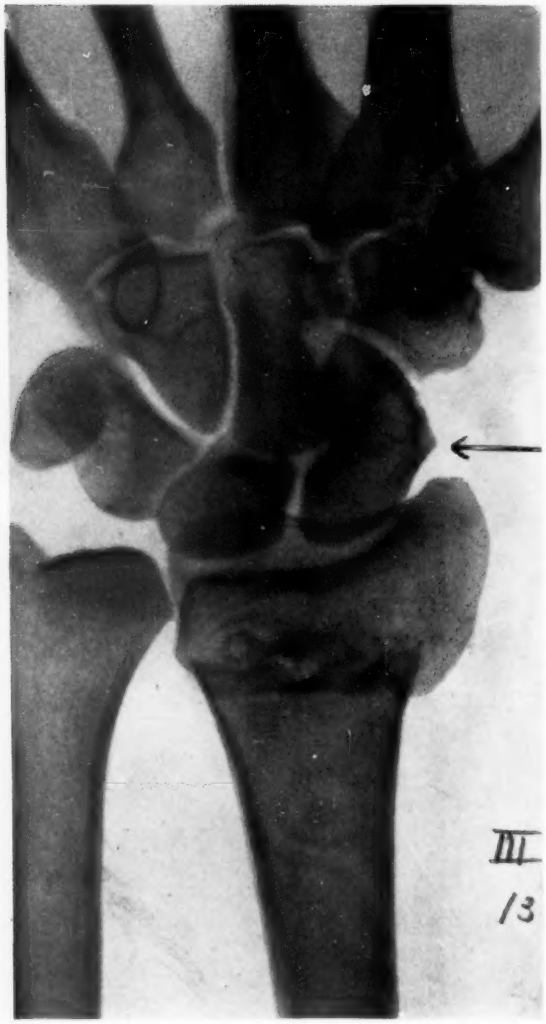


FIG 118.—Fracture of the scaphoid bone, associated with transverse fracture of the base of the radius and fracture of the styloid process of the ulna.

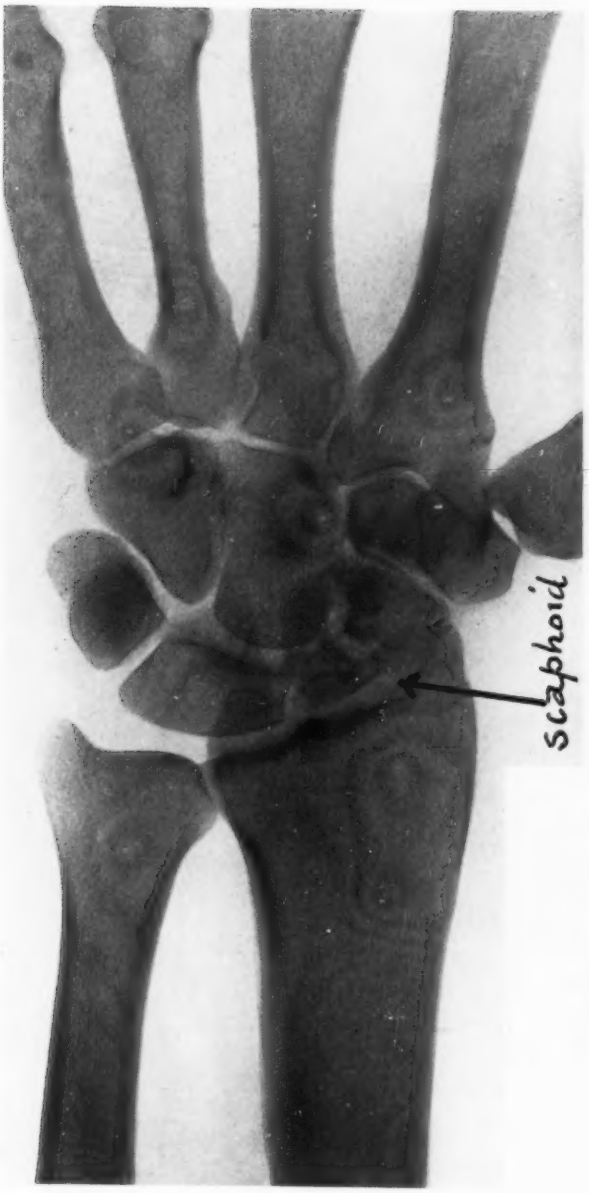


FIG. 119.—Fracture of the scaphoid bone, produced by an automobile crank "kickback."

FIG. 120.—Dislocation forward of the semilunar bone, produced by an automobile crank "kickback."

published their elaborate study on "Fracture of the Carpal Scaphoid and Dislocation of the Semilunar Bone." A large proportion of the cases reported by them were the result of the same kind of traumatism as that which is the usual cause of fractures of the base of the radius, and some of them were associated with recognized fractures of the radius. Among our own cases, in the one from which the skiagraph, shown in Fig. 118, was made a fracture of the scaphoid can be clearly discerned. The fractured scaphoid shown in Fig. 119 and the dislocated semilunar shown in Fig. 120 were both produced by the hyperextension of a wrist caused by a kick back of an automobile crank and singularly enough in the same individual at different times; the scaphoid of the right carpus having been first broken and, three months later, as the result of the same kind of force, the left hand being now used, the semilunar bone of the left carpus was squeezed out of its place as shown in the figure. The radius escaped injury in both instances. Continued tenderness and prolonged disability in a wrist following a fracture of the base of the radius, after repair of the bone has taken place, should awaken suspicion as to the presence of coincident injury to the carpus, and call for careful examination as to its presence.

Associated Injuries to the Periarticular Structures and Diastasis of the Ulna.—When the lower fragment of the radius comprises the whole width of the bone and is carried backward to any degree (Fig. 96) the ligaments that bind it to the head of the ulna now sustain the greater part of the residual strain; and, as a result, first, the hand, carpus and lower fragment rotate in a backward direction around it, as already described on page 9, the contour of the wrist is altered; the radial fragment, thrown into supination, projects on the outer side of the dorsum and the head of the ulna appears more prominent on the inner anterior aspect of the wrist (see Figs. 65 and 67). If the force has become expended at this point, the radio-ulnar ligaments still hold, and no diastasis of the head of the ulna from the radius occurs. In the skiagraphs which have already been presented examination shows no separation of the head of the ulna in a large proportion of them (see Figs. 10, 11, 13, 14, 16, 50, 51, 57, 58, 59, 98, 106, 107, 108). Not infrequently, however, especially when the fall has been from a height or with much violence, the radio-ulnar ligaments are ruptured and the head of the ulna, torn from its radial connections, is driven inwards, forwards and downwards in varying degrees according to the degree of violence inflicted. In some instances, as illustrated in Figs. 52 and 54, the ulna, after being torn loose, is merely forced away from the radius, broadening the wrist and projecting on the ulnar side. Figure

118 shows a greater degree of displacement downwards of the head of the ulna. Compare also Figures 12, 15, 53, 55, 104, 109. Still greater degrees of displacement, some of them very extreme, are presented in Figures 56, 59, 60, 70, 91, 92, 93, 94 and 95. It is in this last class of cases that occasionally the ulna is thrust through the skin. The external deformity produced in these cases of extreme displacement is very marked (see Fig. 121).

It is a misnomer to speak of these conditions as dislocations of the ulna. It is not the ulna that is dislocated or torn away from its attachments to the radius; it is the torn off fragment of the radius, carrying with it the carpus and the hand, that is dislocated and separated in varying degrees from its relations to the ulna. The injuries that are sustained by all the soft tissues about the wrist joint, coincident with the bone lesions that have been described, are extensive and important. Ligaments are violently stretched and partially lacerated even in the minor degrees of injury; sometimes they are entirely ruptured; the synovial sacs of the articulations are badly contused and sometimes lacerated and filled with blood; the sheaths of the tendons, both in front and behind, are injured; in front the projection of the ragged edge of the upper fragment into the midst of the flexor tendons may lacerate their sheaths and irritate the tendons, while behind the stripping of the periosteum and its later continued tension involves in its results the extensor tendon-sheaths with the floor of which it is intimately blended.

Effusions of blood and lymph into the anterior tendon-sheaths and adjacent connective tissue spaces quickly produce a well marked swelling on the front of the wrist above the annular ligament which exaggerates the deformity formed by the bone displacement and may simulate displacement when it has been rectified. On the back of the carpus some swelling of similar character also forms, as a rule. These effusions are firm, are slowly absorbed, especially in the feeble and aged and tend to provoke adhesions along the course of the tendons which they envelop.

Permanent Alteration in Contour of the Base of the Radius.—In a considerable proportion of the cases of fracture of the base of the radius in which appreciable displacement of the lower fragment has taken place some actual permanent alteration in the form of the fragment has been produced so that perfect restitution of the normal contour of the part is impossible by any treatment and some permanent deformity is unavoidable. Some of the cancelli of the lower fragment are crushed and condensed, and in some cases more or less absorption

FIG. 121.—Prominence of ulna and shortening of radius, after fracture of lower extremity of radius with marked backward displacement of lower fragment (see Figs. 60 and 95)

of osseous tissue later takes place, so the bone is permanently shortened and the form of its lower extremity is changed. Such changes in the bone contour are the unavoidable result of the accident itself; they cannot be prevented by treatment, nor can their presence reflect in any unfavorable manner on the treatment given. The possibility of arrest of growth of the radius following epiphysial displacements has already been discussed (page 13). In its least degree this change in the form of the base of the radius is well shown in the radius depicted in Fig. 75. See also Figs. 100, 101, and 102. A higher degree of damage is seen in Figs. 50 to 55, 57, 58 and 60. The most marked change is in those fractures in which the lower fragment is virtually telescoped by the lower end of the upper fragment and its comminuted fragments driven explosively in various directions. See Figs. 61, 62, 63, 64. In the more extreme cases in which the lower fragment is carried at once so far backwards as to clear the upper fragment and ride upon its dorsum (see Figs. 56, 71, 88, 89, 90, 91, 92, 94, 98, 113, 114) such injury to the bony structure of the lower fragment is escaped, and if the lower fragment is completely replaced a fair restitution of the normal contour of the bone is obtained. It is by the failure to fully disentangle this lower fragment and bring it down fully into its proper place that the most marked deformities are perpetuated. If the backward displacement is allowed to remain in any degree, the vacant subperiosteal angle (Figs. 31, 33, 69, 70, 85, 86, 89, 93, 95, 96, 97, 98 and 111–114) left will in time be filled in with new bone, which will enclose the compact lamina of the lower end of the upper fragment to the point where its periosteum had been stripped from it. Any shortening of the radius will make prominent the head of the ulna as the carpus and hand fall to the radial side. In point of actual observation the projection of the end of the ulna on the inner anterior aspect of the wrist is the most noticeable and frequent permanent sequel of this fracture. This projection of the ulna is shown in varying degrees in Figures 67, 121 and 110. The alteration in the plane of the carpal articular facet of the radius, so often remaining, has been already fully discussed in another connection. A further word should be said as to the cause and significance of the persistent protrusion of the head of the ulna. It has already been stated that when the radius has given way the tendency is for the whole hand and the carpus to be carried backward and outward, as in supination, with the broken off fragment of the radius, as it rotates around the head of the ulna. As a result of this movement the back of the radius becomes approximated to the styloid process of the ulna and the head of the ulna is made to project notably upon the

front and inside of the wrist where it is firmly held as long as any backward displacement of the lower radial fragment remains unreduced, or the radius is shortened in its vertical length.

The exact cause of this movement and this locking I have made a subject of frequent experiment. It occurs in experiments on the dead body equally as well marked as in the living body; it is, therefore, not the result of muscular action. Removing integument, annular ligament and superjacent tendons, no change results; entanglement of the styloid process in the annular ligament, therefore, is not necessary for its production. If the greater part of the anterior carpo-ulnar fibres are cut away, no relaxation results. If the triangular fibrocartilage be now exposed, though this be without tension and thoroughly relaxed, the ulna and wrist are still firmly bound in their new relations to each other.

The real cause of these phenomena is now revealed to be the strong fasciculus of the common anterior ligament of the wrist which passes obliquely upwards to the ulnar side to be inserted into the anterior border of the styloid process of the ulna. This fasciculus has already been mentioned as the medium through which this styloid process is so frequently broken off. The obliquity of its direction and the extent and place of its insertion govern the movements which the movable parts attached to it may make. As long as the carpus and the attached fragment of the radius are in backward displacement, this fasciculus is kept tense and all rotation is prevented.

Prominence of the head of the ulna with widening of the wrist and loss of the anterior projection of the articular lip of the radius and the imposition of a more or less backward inclination upon the plane of the carpal articular surface of the radius are therefore the most common permanent alterations in the anatomical configuration of the wrist as the result of a fracture of the base of the radius. The result of these anatomical changes is to perpetuate in some degree in many cases the deformity which immediately followed the accident. The inward and forward projection of the lower end of the ulna may persist even when there is no appreciable deformity of the radius, through lack of full restoration of the close ligamentous bands that before the injury tied it to the radius.

The bony deformity, even when marked, as a rule entails of itself but slight if any functional disability; the chief sources of disability following this injury are the consequence of the periarticular changes, such as the matting of tendons and the contracture of the ligaments and the formation of fibrous bands and adhesions due to the laceration and irritations of these structures consequent upon the bony injury

and displacement. Too prolonged immobilization and the undue pressure of retention splints too forcibly secured may aggravate the amount of disability referable to the injury itself.

The diagnosis in many cases is self declared the moment the wrist is seen, so characteristic and plainly marked is the deformity (Figs. 65–68). The other cardinal signs of fracture, crepitus and abnormal mobility are often obscured, even prevented, by the amount of displacement and impaction and the resistance of untorn fibrous connecting bands, all of which conditions have been considered in preceding pages.

In cases in which the degree of displacement, and consequently the extent of deformity, is but slight, careful palpation will usually enable the surgeon to recognize the loss of the projection formed by the anterior lip of the sound bone and some abnormal elevation of the lower fragment on the back of the wrist. In the absence of any appreciable displacement the lesion of the bone may still be inferred if pressure elicits a point of special tenderness on the outside of the radius near the base of the styloid process, since such tenderness at that point could not result from any ligamentous rupture. Forward displacement of the head of the ulna is recognized at once on inspection of the wrist and when present indicates the coexistence of fracture of the radius; fracture of the styloid process is indicated by special tenderness at its base; manipulation may elicit undue mobility and crepitus, but it is rarely so completely torn away as to become notably displaced.

Fracture without great displacement is often overlooked, and being regarded as a simple sprain is permitted to heal without effort to prevent deformity. In every case of injury to the wrist following violent backward flexion, accompanied with ecchymosis, local swelling and impairment of function, the presence of fracture is to be inferred, even though one fails to elicit any of the signs of it that have been mentioned.

The final authority as to the character and extent of the injury is the X-ray, and resort to it should be made whenever practicable both to confirm and correct the diagnosis and later to demonstrate the degree to which proper reposition of the fragments has been secured.

In all doubtful cases the information to be derived from the X-ray plate is most desirable and as a help to the surgeon in directing his treatment is invaluable. Both anteroposterior and transverse views should be taken.

Treatment.—If displacement exists its accurate reduction is of first importance. The chief obstacles to ready and perfect reduction are the impaction or entanglement of the uneven surfaces of the fragments, and the tension of the untorn periosteofibrous band which still unites

them at the back. The latter can be overcome at once by placing the hand in dorsal flexion; while the hand is still in this position extension will disengage the fragments, and firm thumb pressure upon the back of the lower fragment will push it forward into place. This method of manipulation is well shown in Fig. 122.

If the hand is then brought into palmar flexion while extension is continued and the thumb pressure on the back of the lower fragment is still maintained, the fragments come into normal relations, the fracture surfaces fall together and the normal contour of the bone is restored. Figs. 124 and 125 are from skiagraphs of a wrist of a woman who had slipped on the pavement and had received the brunt of her fall upon her extended hand. The fractures sustained are shown in Fig. 124. The amount of backward displacement was sufficient to produce a typical silver-fork deformity of the wrist, and to wrench off the styloid process of the ulna as shown in the skiagraph. I saw her within a few minutes after the accident and subjected the injured wrist to the manipulations described. The perfection of the reposition is shown in the skiagraphs (Figs. 124 and 125) which were taken the next day so as to secure an X-ray record of the case. No general anæsthetic was required in this case to facilitate the reposition. Indeed I have rarely felt any need of such anæsthesia in dealing with a recent fracture of the wrist.. If the patient is an hypersensitive or apprehensive individual or a child ether or chloroform will naturally greatly assist the surgeon in his manipulations. The displacement is to be overcome *arte, non vi.* The manipulations do not require the exercise of great force nor do they inflict excessive pain.

Impaction of whatever degree is easily broken up after the tense, periosteal connecting band (see page 14) has been relaxed. If the impacting force has been great the lower fragment will be comminuted and the lower end of the upper fragment will in no sense be gripped by the pieces of the lower fragment by which it is surrounded.

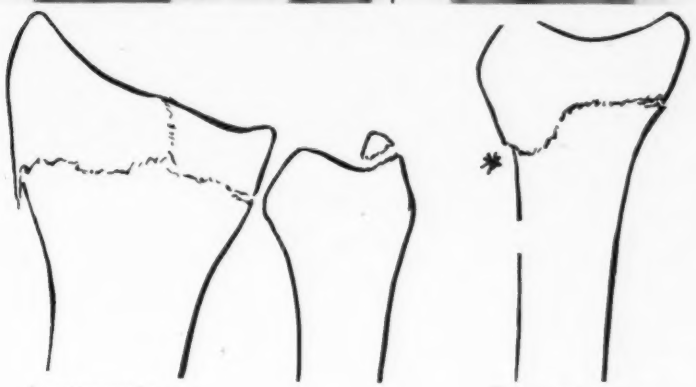
If the lower fragment has been carried backward so far as to ride on the dorsum of the upper fragment—a not infrequent occurrence—all interosseous penetration is absent and the chief force that causes the displacement to persist is the tension of the stripped up dorsal periosteofibrous bands still holding the two fragments together (see Figs. 33, 69 and 89). It is not necessary to rupture these to any extent, if the manœuvres of relaxation as have been described are resorted to.

These remarks apply particularly to the most frequent forms of displacement in which a backward movement of the lower fragment is the chief and most important element. In those rarer instances in which the upper fragment has telescoped the lower fragment in such manner as

FIG. 122.—Dorsal hyperflexion with extension of disengaged lower fragment.

FIG. 123.—Extension continued, thumb pressure on back of lower fragments; final palmar flexion.

FIG. 124. FIG. 125.



Anteroposterior view. Transverse view.

FIGS. 124 and 125.—Fracture of base of radius with comminution and backward displacement of lower fragment of radius with moderate impaction. Skiagraph taken after reposition to show final adjustment of the fragments secured. Note the persisting slight change in the plane of the carpal articular surface of the radius due to the mutual compression of the bony lamellæ along the posterior portion of the fragment at the point marked by the star.

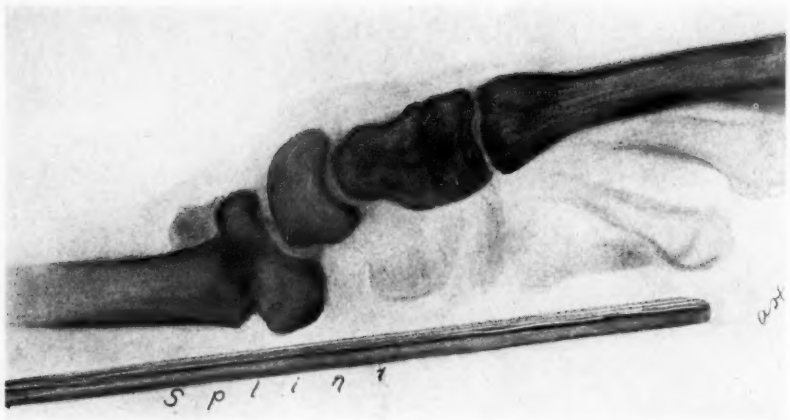


FIG. 126.—Showing effect of palmar splint to maintain or reproduce backward displacement of the lower fragment after fracture of base of radius. From a skiagraph taken three months after injury; original backward displacement still unreduced; fracture healed with deformity.

FIG. 127.—Showing position and shape of special palmar pad to protect from pressure productive of backward displacement the lower fragment of a fractured radius involving the base.

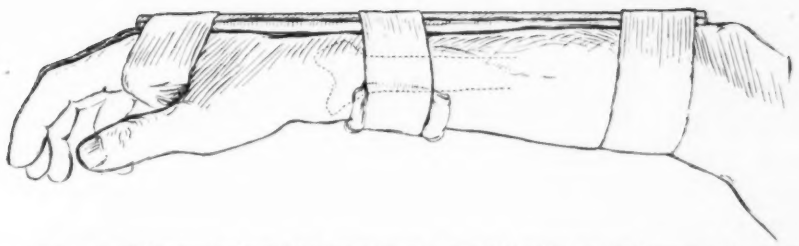


FIG. 128.—Diagram to show the adaptation of a straight splint to the dorsum of the wrist. Note the even plane of the dorsal surface of forearm, wrist and hand requiring minimum amount of padding; note the projection to the palmar side of the articular lip of the base of the radius, note the pad adjusted to the concavity of the palmar side of the base of the radius and secured so as to secure the articular lip from pressure that may displace it backwards if separated by fracture.

FIG. 129.—Diagram showing adaptation of the turbinated splint to the conformation of the hand, wrist and forearm. Note the use of a compress to lift the projecting lower margin of the articular expansion of the base of the radius from the pressure of the splint.

to split it and drive the pieces of the lower fragment in various directions, the best possible reposition of the fragments is to be secured by simple direct extension with approximation of the disruptured pieces by thumb and finger pressure as in a moulding process.

Some permanent shortening of the radius from condensation of the tissue of the lower fragment is unavoidable in all cases in which the upper fragment is impacted in any degree into the lower one. Such shortening will make the end of the ulna more prominent on the inner side of the wrist; the greater the shortening of the radius the more prominent the ulna (see Fig. 121). Second only in frequency to the alteration in the plane of the carpal articular surface of the radius (see page 8 and Figs. 76, 79 and 80), is this slipping away of the head of the ulna from its proper relation to the radius. The normal projection of the ulna on the dorsum of the back of the wrist disappears and an abnormal projection of it on the front and inside of the wrist persists permanently. The less the impaction and the more perfect the replacement of the lower fragment of the radius in its normal relation to the shaft of the bone the less the tendency of the ulna to show this deformity. In the further care of such a fracture attention will be required to secure and maintain full approximation of the ulnar head to its normal relation in the lateral articular facet of the radius until normal ligamentous bands have been reformed.

Ordinarily there is but little tendency to renewed displacement after reposition provided the part is protected from further direct force. Regard must always be given to the fact that any pressure brought to bear upon the palmar or anterior surface of the carpo-radial region will bear upon the projecting anterior lip of the lower fragment and may crowd that fragment back to the plane of the shaft of the bone (see Fig. 126) even though full restoration of the normal contour of the base of the radius had been secured by the surgeon before the retentive dressing was applied. Anteroposterior pressure also tends to crowd the soft tissues in between the radius and ulna, and, forcing the ulna away, to renew and perpetuate its diastasis. The first indication in the planning of a retentive dressing therefore is the adaptation to the front of the forearm of a graduated pad of proper thickness so placed that it shall shield the anterior lip of the lower fragment from pressure (Figs. 127, 128 and 129). The lower margin of this compress should fall about one-half inch above the carpo-radial articulation. It should be about three-eighths of an inch thick at this lower edge, and should extend upwards from two and one-half to three inches. It should be wide enough to wrap part way around the ulna so as to give support to that

bone also when the later circular roller is applied. A folded gauze compress answers fully for such a pad.

In the further care of the injured part the indications are to give support and immobilization, with equable compression to limit effusion, and to maintain approximation of divided tissues while repair goes on. With the subsidence of the primary wound reaction precautions to maintain the mobility of the wrist and finger joints require attention. In very many cases, in addition to the graduated compress already mentioned, a flannel roller bandage and a sling will be all the apparatus required. The slightly elastic flannel roller binds the strained and shattered parts of the wrist together and gives an agreeable sense of security and support. At this first dressing allowance must be made for the primary traumatic swelling that follows the injury, and the bandage must later be loosened or cut, whenever its constriction becomes a source of discomfort; as the swelling subsides it should be tightened again.

This circumferential compression is especially important to maintain the lower fragment and the carpus in their proper position to the ulna. It is further reinforced during the after-treatment by keeping the forearm supported on its ulnar side in a narrow sling, not extending forward beyond the distal end of the ulna, in which position the weight of the unsupported hand and wrist is an additional force tending to press the ulna into position.

The feasibility of satisfactorily treating fractures of the base of the radius by so simple an apparatus as a flannel roller and a compress I learned very early in my experience in dealing with such fractures from the teaching of the late Dr. E. M. Moore, of Rochester, N. Y., who was led to it by his views as to the importance of supporting the ulna in the course of the treatment of such injuries.

In my earlier writings on this subject I emphasized the value of the method, advocating at that time an adhesive plaster strip encircling the wrist as the chief element of the apparatus required. In part this was one form of protest on my part to the wrongly applied and too prolonged use of immobilizing splints, almost universally employed in the treatment of this injury, to which I was convinced that much of the unfortunate results so often attending this fracture were due. I have treated a large number of broken wrists during the past thirty years without the use of a splint with such good results that they have fully justified me in the practice. Nevertheless, I have not been unmindful of the distinct advantage of the protection which a properly applied splint could give in these injuries, a protection which is more especially called

for in the presence of much comminution of the lower fragment, and in those cases in which marked displacement demonstrated the association of extensive sprain and laceration of the soft parts.

Whether indeed to the dressing should be added a splint will generally depend upon what may be called collateral circumstances. In cases of those who are young, or are careless, or are apprehensive, the additional protection of a splint is a wise precaution to be used if the surgeon also remembers that its prolonged use may create finger and wrist stiffness and by its pressure deformity may be perpetuated or an ischæmic paralysis may be induced. For a young surgeon also it will in most cases be more discreet not to disregard the popular sentiment as to the necessity of a splint in the treatment of a fracture. If a splint is to be used a light straight posterior splint supplies fully all the indications for splint support and immobilization (Fig. 128). It should not be wider than the wrist itself lest it interfere with the lateral support to the ulna; it should extend from the upper part of the forearm downward only to the heads of the metacarpal bones, so that the fingers shall not be confined by it. It should be well padded. The graduated pad to fill up the concavity of the radius above the articular lip on the palmar side will already have been adjusted as recommended (page 23), shown also in Figs. 127 and 128.

Special support to the ulna should be given by making the palmar pad wide enough to project on the inner side of the wrist sufficiently to enwrap the inner side of the ulna, or by the adaptation of a special pad to support the ulna. Over all should be applied a roller bandage—preferably of flannel—which should leave the fingers and the thumb free. As soon as the primary congestive reaction from the injury has subsided, that is from the fourth day, the thumb and fingers should be frequently and systematically flexed, and after the first week the splint should be daily removed and the wrist should be massaged and moved; by the end of the third week the splint should be discarded altogether, and thereafter active and passive movements of the wrist and fingers, with massage, be practised systematically until the normal function of the parts has been restored.

Special Forms of Splints.—Many special forms of splints have been devised for this injury, most of them intended to maintain certain positions of the hand on the supposition that thereby displacements could be corrected or prevented. They are with few exceptions based on incorrect views as to the cause of displacement and disability and none of them possess such special advantage as to justify their description here. An exception to this statement may be made in the case of such splints

as the Coover, the Levis and the Walker splints which are anterior splints molded in such a way as to accommodate the irregularities of the palmar side of the hand, wrist and forearm, and hence tend to lessen the disadvantages of the ordinary straight anterior splint. With proper padding (Fig. 129) they may be made to give the needed support to a fracture without exerting undesired pressure on the anterior face of the lower fragment, and they are comfortable to the patient. One who wishes to use these splints must have a variety of sizes—rights and lefts—to adapt them to various ages and sizes of patients. Their use does not in any degree lessen the importance of first fully readjusting the fractured parts. It is only after full reposition has been secured that they may help in the further care of the case. In 1881 Dr. Coover, of Harrisburg, Pa., sent me a full set of various sized splints, devised by him, so shaped out of a light pine fabric that the thenar eminence of the hand and the normal lateral angle of the hand with the forearm were provided for (see Fig. 130). During the thirty-five years that have elapsed since I received them, I have used these splints many times; I have most of them still in good condition for I have seen to it that they were not carried away permanently by those in whose cases they were used. The manner of their application is shown in Fig. 131.

Treatment of Fractures Already Healed in Deformity.—It is not infrequent that fractures of the base of the radius are permitted to heal without adequate effectual attempts at adjustment of the primary traumatic deformity having been made. Every grade of the deformities which have been recognized as due to any degree of this injury may remain as the permanent result. In general the functions of the wrist and hand are ultimately so far restored, even in cases of marked deformity, that all the ordinary activities and possibilities of usefulness of the member are regained. The greatest and most prolonged disabilities are due to adhesions in the tendon-sheaths and among periarticular fibrous structures and to muscular degenerations caused by undue and prolonged splint pressure and immobilization and not to the bony malformation.

In comparatively recent cases, by that I mean at periods of from three to six weeks after injury, there still remains ground for hope that by breaking up the new formed and still soft bonds of union, either by manipulation or by a chisel through an open wound, a better position of the fragments could be obtained and the worst of the deformity removed. When, however, one reflects as to the frequency with which permanent alterations in the texture and contour of the lower fragments have unavoidably resulted from the injury sustained, and also how extensive are the contractures of the periarticular tissues and the rup-

FIG. 130.—The turbinated-split (Coover) for fracture of the lower extremity of the radius and other injuries of the wrist.

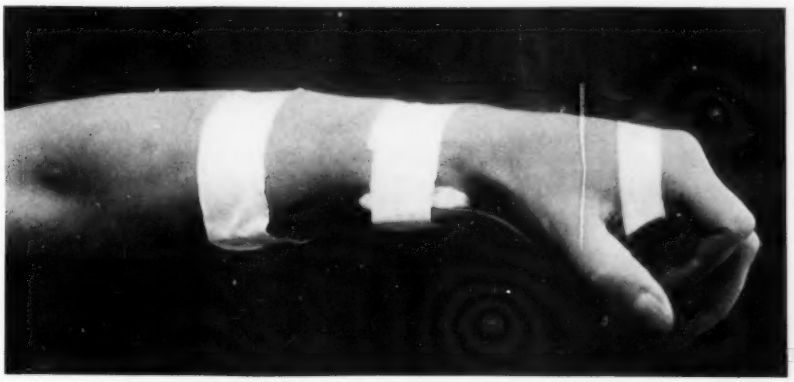


FIG. 131.—Palmar turbinated-split applied. Note thenar eminence received in the depression provided for it; note projecting anterior lip of radius secured from pressure by special compress adjusted; note support given by encircling adhesive strip to prevent tendency to renewed backward displacement of the lower fragment; note freedom of thumb and fingers for active movements.

tures of ligaments that cannot be reformed as before the injury, one will not be too sanguine as to the ultimate benefit which he may secure to such a patient by operative interference. In a number of instances I have exposed a badly united fracture line involving the base of the radius by an incision over the dorsum of the radius reaching from the middle of the carpus below upwards as far as required to secure needed exposure and access to the seat of the fracture for the necessary manipulations. By blunt dissection the lower end of the bone can be readily exposed; the periosteo-ligamentous-tendinous flaps can be held aside by retractors, and a chisel used as freely as may be necessary to re-establish the fracture in its original plane. The surrounding restricting fibrous bands will have to be divided with sufficient freedom to make possible the easy replacement of the loosened lower fragment in its normal position and prevent any tendency for it to be drawn again into its faulty position. This having been accomplished, the wound is sutured and the part dressed and cared for as if a recent fracture. The results of such attempt at my hands have been sufficiently good to encourage their repetition in similar cases. I have thought that I have not been sufficiently free in dividing the periarticular fibrous structures in some of them to have secured as perfect a result as might possibly have been attained. I have not had occasion to resect a projecting ulnar head, but it cannot be denied that such a procedure would be indicated in some cases.

VOLKMANN'S ISCHÆMIC PARALYSIS AND CONTRACTURE*

By Alfred S. Taylor, M.D.
of New York
VISITING SURGEON, FORDHAM HOSPITAL; NEUROLOGICAL SURGEON, HOSPITAL FOR RUPTURED AND CRIPPLED

Since Volkmann, in 1881, published his first communication on "Die Ischämischen Muskellähnumgen und Kontrakturen," much work by many individuals has been done in both the experimental and clinical fields to determine the etiology, pathology and treatment of this condition.

The views expressed by the many writers on these various phases of the subject differ widely.

Inasmuch as this form of so-called paralysis is not uncommon, and especially since its incidence is almost entirely due to bad initial management of injured extremities, it is desirable that an attempt should be made to correlate the varying views as to etiology and pathology and from the resultant findings to deduce the principles of treatment, both of injuries likely to develop this condition and of the condition itself at its incidence and in its fully developed form.

Only those cases occurring in the upper extremity will be considered.

Concerning its incidence it is a matter of record that this condition occurs in children between one and fourteen years of age, and almost always secondarily to fractures about the elbow and upper forearm region, in which the primary treatment is such as to cause serious interference with the circulation plus direct pressure at and below the site of the fracture. This is brought about by tight bandages, splints, or position (acute flexion at the elbow for example).

The different views as to the etiological pathology of the condition may be indicated by the following brief schedule:

1. Primarily muscle changes—Volkmann, Leser.
2. Nerve damage primarily—Chvostek, Mannkopf and Lapinski.
3. Primarily muscle and secondarily nerve damage—Hildebrand.
4. Muscle and nerve damage, simultaneously and co-ordinately—Bardenheuer.

This wide divergence of views probably results from the equally wide divergence in the clinical manifestations of different individuals in the group.

In trying to determine which view is most likely to be correct it is

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important to remember that in a considerable percentage of the cases the loss of voluntary movement and the rigid contracture of the muscles occur simultaneously (in some cases the contracture starts as late as seven weeks after the injury, but the muscles are rigid and inelastic even before the shortening occurs), and that both the loss of power and contracture occur in the same muscles.

Since the paralysis which follows injury of a nerve is always a flaccid paralysis, a fact beyond dispute, and since the contractures which involve muscles in a partially paralyzed extremity occur not in the paralyzed muscles themselves, but rather in their no-longer-opposed antagonists, it is evident that nerve injury cannot be the prime factor inducing the *condition under discussion.* How important nerve injury, both primary and secondary, is, as a complication, will be indicated later.

Again, Leser has demonstrated experimentally that shutting off the arterial supply of an extremity resulted in flaccid paralysis of the muscles. On the other hand he demonstrated on dogs, that a tight bandage on one of the extremities, without previous injury to nerve or artery, would cause, after five or six hours, a rigidity of muscles with loss of function, quite comparable to the *condition under discussion.* If at the end of the five or six hours, when the extremity had become rigid, the bandages were entirely removed and the dog allowed to run free, complete recovery quickly ensued. If, however, the compression was removed but the dog was prevented from using the extremity, loss of function and contracture developed steadily to full degree. These important observations will be referred to again under the consideration of treatment.

Since nerve injury, or complete arterial obstruction, or both combined cause only flaccid paralysis, which is in no way comparable to the ischæmic paralysis and contracture under discussion, they cannot be considered as essential etiological factors.

It remains to be determined whether primary injury to muscle substance, with the consequent changes, will explain the immediate and remote pictures, both pathological and clinical, which are found in these cases.

Volkmann,[1] in his original publication stated that, as a result of interference with arterial supply aggravated by venous congestion, the muscle substance, deprived of its oxygen, underwent coagulation necrosis and developed localized rigor mortis with contracture. As the ischæmia was not complete gangrene did not occur.

Leser [48] and Horwitz [41] have demonstrated that direct compression of the muscles for more than six hours will cause the typical muscle

changes invariably even where there is no damage to the nerves or vessels other than that due to compression, whereas damage confined to the vessels and nerves never caused the characteristic changes. Moreover, in the acute stage, the muscle substance is white, almost as if cooked, and has lost its elasticity and vascularity.

At a later stage when the contracture is developed, the muscle substance is diminished in volume, hard, stiff, dry, yellowish-brown, avascular and inelastic.

In the final stage hard fibrous tissue replaces the muscle substance more or less completely according to the severity of the individual case.

These muscle conditions are entirely different from those found where the arterial or nerve supply or both have been cut off, because in such cases the muscles are flabby, and while degeneration and cicatricial replacement may occur, the result is always an atrophic flabby mass, instead of the stony hard cicatricial mass suggestive of an inflammatory residue, which is always present in the ischæmic cases.

Moreover, the maximum change in the muscles is at the site of the greatest local compression, *i.e.* the flexor aspect of the forearm just below the elbow. Fig. 1 is a photograph of a section taken from the middle of the flexor group of muscles about one-third the length of the forearm below the elbow in Case III. No muscle substance can be made out.

From the preceding facts the deduction is, that the primary underlying condition in these cases is one of direct damage to muscle substance followed by the usual cicatricial changes and contractures.

In addition to this fundamental muscle damage there may occur complicating lesions of the nerves and vessels passing the elbow. When such complicating lesions are present the muscle damage is naturally augmented and recovery delayed or prevented by the interference with the circulation and innervation of the involved muscle.

Of the nerves passing the elbow, one or all may be involved, the ulnar being first in frequency and the median next. The injury may occur primarily as a part of the accident, or secondarily as a result of pressure and ischæmia from the dressings, or more remotely as a result of constriction by the shrinkage of the cicatrized mass of muscle. This nerve damage may vary all the way from complete severance of the nerve to very slight interference with function.

Thomas [27] found evidences of nerve involvement in 62 out of 107 cases he tabulated (about 58 per cent.) in most of which he believed it to be a late development from cicatricial pressure.

The presence of a complicating nerve lesion renders the prognosis more dubious both as to speed and completeness of recovery.

A serial picture of the stages as they occur in the development of this condition will be most helpful in the consideration of the symptoms, prognosis, and especially the treatment indicated.

One anatomical fact is important; the whole flexor group of forearm muscles is surrounded by a firm, unyielding covering of aponeurosis and bone. The extensor muscles are covered by a similar envelope but they are seldom involved in the process. The flexor group bears the maximum damage, since the muscles form a prominent mass, surround the large vessels and are therefore liable to greater traumatic infiltration. From their prominence, due to both natural size and greater infiltration, they suffer the maximum damage from any form of compression dressing.

When the injury occurs, usually a fracture in the elbow region, there is an infiltration of the soft tissues first with blood and later with œdema which rapidly increases the tension beneath the unyielding envelope just mentioned. Increased tension interferes with return flow in the veins with consequent increasing venous congestion and swelling. Gradually the arterial flow is diminished by the increasing subaponeurotic pressure and there approaches a condition of stagnation in the nutrition of the muscle substance.

If, in addition to these internal disturbances of muscle nutrition, there is added external compression by means of tight splints, bandages or extreme flexion, conditions are ideal for the production of ischæmic paralysis and contracture. Yet, of all the children with fractures about the elbow who are badly treated, only a small percentage develop this lesion. This fact would suggest the possibility of a fundamental deficiency in the muscle nutrition of those in whom it does appear. When once the myositis is fully developed there is a replacement of muscle tissue by connective tissue which contracts and gives the typical end result.

The pathological changes just described may involve only a small portion or the whole of the muscle substance, and between these two extremes there may be any number of gradations. In the same way there may be any number of variations in the amount of injury, both primary and secondary, to the nerves and vessels.

To keep these facts clearly in mind, is of prime importance in the consideration of prognosis and treatment.

The symptoms are characteristic, and may be considered as immediate and remote.

Immediate: When the fractured arm has been cared for and put up in a tight dressing, the child soon complains of pain, which is so persistent and severe as to prevent rest or sleep, day or night, and to cause constant outcry, which is usually explained as resulting from a highly nervous temperament, since all fractures are painful the first few days.

Accompanying, and sometimes slightly preceding the onset of severe pain, there is a rapid swelling and cyanosis of the fingers, hand, and forearm.

In the more severe cases large blebs appear on the exposed areas of skin, while skin sloughs appear at the points of maximum pressure of the dressing, being most common on the flexor surface of the forearm just below the elbow and on the ulnar side at or just above the wrist.

If, in spite of the above symptoms, the dressings be left undisturbed, the pain and swelling gradually disappear after the first few days. During the height of the pain and swelling, there is often marked constitutional disturbance as indicated by a temperature from 102° to 104° F., headache, malaise, anorexia, etc.

The characteristic changes in the muscle substance occur in from five to forty-eight hours, depending upon the amount of subaponeurotic swelling and degree of external compression applied.

When the muscle change has occurred, it is indicated by loss of voluntary motion, by more or less rigid resistance to passive motion, and, if the dressings are removed, the whole muscle mass has a hard, brawny feeling beneath the finger.

The flexion contracture of the fingers may start within six hours, or it may not begin until as late as six weeks. In either case it is progressive over a period of about three months, after which there is practically no further shortening of the muscles involved. From this point on there may be a gradual increase in the flexion deformity, as a result of the steady growth in the length of the bones with no compensatory increase in the length of the cicatrized muscles.

In the early stage, the contracture shows itself in the form of marked flexion of the second and third phalanges, with extension at the metacarpophalangeal joints. As the contracture progresses this deformity is exaggerated and there is added an increasing flexion of the wrist and a slight flexion of the elbow in semipronation.

The characteristic feature of these cases when well developed lies in the behavior of the fingers and wrist toward passive motion. If the wrist be forced to the fully flexed position, the fingers can be passively

(and oftentimes voluntarily) extended to a straight line. If now the fingers be held fully extended, extension of the wrist joint is found to be impossible unless sufficient force is used to rupture the flexor tendons. On the contrary, every degree of wrist extension is accompanied by a corresponding amount of flexion in the fingers, until extension at the wrist is limited by the full flexion of the fingers and this point is usually reached before the wrist has been quite extended to a straight line.

During these manipulations the flexor tendons stand out at the wrist and in the forearm like whip-cords. The upper forearm is much diminished in size, and the mass of flexor muscles is more or less completely replaced by a smaller, hard, inelastic mass of cicatricial tissue, obviously the cause of the changes in the mechanical possibilities of the extremity.

When the initial dressing has produced skin sloughs either just below the elbow or at the wrist, as previously mentioned, infection usually occurs, and produces discharging wounds which are many weeks in healing because of impaired nutritional conditions.

In some cases the infection penetrates into the muscles of the upper forearm, or among the tendons at the wrist-joint, adding materially to the muscle damage and later cicatricial fixation of the extremity.

Thomas [27] in his series of 107 collected cases found scars from sloughs present in 37 cases. Symptoms due to nerve complications occurred in 62 out of the 107 cases in the same series. The ulnar and median nerves are the ones involved as a rule.

The damage to these nerves may be primary at the accident, in which case there will be a loss of function, sensory and motor, corresponding to the extent of damage to the nerve substance.

The nerve damage may be secondary to the pressure produced by the infiltrated muscles and tight dressings, the effect being enhanced by the ischæmia. In this case nerve function is apt to be diminished in activity rather than abolished, although entire loss of function may occur in extreme cases.

Finally nerve damage may occur after several weeks, when it is due to pressure from cicatricial contracture of the involved muscles. Here again, function is more apt to be impaired than totally lost.

In both the ulnar and median nerves loss of motor power can be made out only by an examination of the intrinsic muscles of the hand which are not involved by the " ischæmic process," whereas all the flexor muscles in the forearm have lost their voluntary motion because of

their intrinsic disease, whether or not their motor nerves have been damaged.

The ulnar nerve supplies all the intrinsic muscles of the hand except the abductor pollicis, opponens, and outer half of flexor brevis pollicis which are innervated by the median.

With the long flexor tendons in a state of rigid contraction it is obvious that any examination of these small muscles must be difficult and very unsatisfactory in results, especially in young children who have recently undergone the hard process of acquiring the deformity.

Determination of the condition of the ulnar nerve is less difficult because almost any child will try to separate and approximate the fingers, and the power to do this indicates an intact ulnar supply to the interossei muscles.

In the later stages of the condition, atrophy of the thenar, hypothenar, and interossei muscles would indicate at once serious damage to the corresponding nerve.

Careful repeated examinations of sensation give reliable evidence as to the condition of the nerves, diminution or loss of sensibility indicating corresponding degrees of damage. Repeated examinations are necessary because young children are inconsistent in their responses to stimuli, so that an average must be arrived at.

Nerve injuries are followed also by trophic disturbances, evidenced by the thin glossy skin, coldness, cyanosis, which are most marked in the fingers, as well as by the thickened, brittle, cross-ridged nails. Ulcerations appear at the finger tips upon the slightest provocation.

The difficulties of a neurological examination are greatest and the results least satisfactoy during the primary stages of the condition, in addition to which the many troubles of the practitioner prevent him from thinking of it, so that records are usually lacking.

In general terms, the prognosis is distinctly unfavorable and is rendered more so in proportion to the amount of muscle substance which has undergone disintegration and will therefore be replaced by cicatricial tissue.

When present, skin sloughs followed by infection and slow healing sinuses, and nerve injuries of greater or lesser degree, add unfavorable elements to the outlook, as does delay in starting appropriate treatment.

To give an accurate prognosis at the start in the individual case is very difficult, because it is scarcely possible to determine the exact extent, degree and distribution of the injuries to the muscles, nerves and vessels. This statement applies as well to the early stages of the fully developed contractures (see Case II).

As previously emphasized the muscle damage may vary anywhere from complete degeneration and cicatrization of all the muscle substance, to a very mild degree of damage. It is obvious that complete degeneration and cicatrization would give an absolutely hopeless prognosis, regardless of treatment, and that a very mild degree of damage would give a good prognosis, almost regardless of treatment.

In the intermediate grades the prognosis depends essentially upon the amount of muscle damage but is more definitely influenced by proper treatment. The great majority of cases belong to the intermediate grades.

The great difficulty lies in determining clinically just how much muscle has been involved, because a small amount of cicatricial tissue properly distributed will cause the marked contracture deformity and rigidity characteristic of the condition, and will resist completely any justifiable amount of force used in an attempt to cause passive extension of the fingers and wrist. Resistance to passive extension, then, is not a reliable criterion.

Palpation of the flexor muscles in the upper forearm may help somewhat, since, in the milder cases, they do not present so solid an induration. Here, also, however, an element of error is present because the deep aponeurosis of the forearm is so often thickened as to give a resistance which obscures the feel of the mass beneath it.

In the small proportion of cases in which the electrical tests can be made satisfactorily, a positive reaction by the flexor group to either current would indicate the presence of some uncicatrized muscle and therefore improve the prognosis. On the other hand, cicatricial tissue may be in such preponderance as to prevent any evidence of reaction on the part of viable muscle which is still present.

These difficulties in relation to prognosis are well illustrated by Case II in which one of our best known surgeons said that the only hope lay in resecting both bones of the forearm and even that gave but little prospect of a useful hand. However, to the surprise of every one concerned, without any operation, there was a practically complete recovery after six weeks of treatment. That could mean only that the muscle damage was nothing like as extensive as the clinical examination seemed to indicate.

Nerve damage adds an element of delay to recovery, and if the nerve is not successfully repaired there is a corresponding permanent failure in recovery.

Likewise damage to the great vessels of the extremity delays and may permanently impair recovery.

Great delay in instituting proper treatment is unfavorable since old, firmly contracted cicatricial tissue is more difficult to influence, and old nerve injuries are somewhat less satisfactorily repaired.

It seems clear that an accurate prognosis cannot be formulated in the individual case, and that a fair estimate of the final outcome can be given only after a considerable period of appropriate treatment.

To evolve a rational method of treatment it is necessary to appreciate:

That the fundamental disturbance is a traumatic myositis, accompanied by marked infiltration and œdema in a group of muscles confined in a close fitting inexpansible envelope of aponeurosis and bone, aggravated by external compression:

That the muscle substance is replaced to a greater or less extent by connective tissue which contracts and causes the characteristic deformity:

That the nerves and vessels may be more or less injured:

That, clinically, it is difficult if not impossible to determine the exact amount of damage present in the individual case.

Prophylaxis is of great importance. As a general principle fractures should be reduced and immobilized at the earliest possible moment after their occurrence, and this principle applies to the group under discussion. However, there should be special precautions in dealing with all fractures about the elbow region in children. Manipulation should be gentle, to avoid additional traumatism and swelling. Fixation in extreme flexion is dangerous because of circulatory disturbance both in veins and arteries. Where it seems essential very frequent observation is imperative.

Splints should be padded so as to avoid localized pressure spots.

Dressings should not be too tightly applied. They should allow for increasing œdema. The extremity should be elevated.

Once reduction and fixation have been accomplished, the extremity should be watched with the greatest care. For the first forty-eight hours, inspection by the attending physician every five or six hours would be the ideal arrangement, since the condition may become fully developed in that period. This plan is seldom feasible. Next best is to have the parents instructed to call the physician at once, if there is unusual and persistent complaint of pain which prevents sleep, and especially if the pains are accompanied by cyanosis, swelling and possibly some rigidity of the fingers.

As soon as this combination of symptoms makes its appearance, all dressings should be removed, the elbow placed at a right angle or

more to aid circulation, the extremity elevated, and the site of fracture firmly supported by hand, while gentle massage is given from the fingers upward, followed by passive motion applied to the fingers and wrist. (Active motion if the child is able. See Leser's Experiments on dogs.) All these procedures aim to reduce the swelling and improve the circulation and nutrition of the muscle substance which is threatened with degeneration.

If the swelling diminishes, or at least does not increase, and especially if there is less pain, and the cyanosis and rigidity of the fingers are lessened, the extremity may be lightly fastened to some support and left in the elevated position. For the time being the fracture itself is of secondary importance, the chief care being to give enough support to avoid further injury to the soft tissues by the bone fragments, and to leave the limb in position for the best circulation.

In some cases, if not in all, a general anæsthetic would seem advisable for the above procedure.

If, in spite of the treatment just outlined, the pain, swelling, cyanosis and rigidity increase, we are dealing with a group of muscles under great compression beneath the unyielding deep aponeurosis, threatened with disorganization, and the only hope lies in applying the principle of decompression. If the skin itself is not much involved by the swelling, a subcutaneous split may be made in the aponeurosis over the whole length of the flexor muscle bellies from the elbow down. If the skin is hard, brawny and shiny, it should also be split full length with the aponeurosis. Sterile dressings are applied without pressure. Of course, general anæsthesia and all aseptic precautions must be used.

After the dressings are applied, gentle passive motion of the fingers and wrist should be given, to help restore the muscle nutrition, while the patient is recovering from the anæsthetic.

Up to this point nothing can be done for nerve injuries, even if they are known to have been caused at the accident, because of the unfavorable condition of the tissues.

The treatment thus far outlined has never been applied to the living human subject, but it seems logically to follow from the consideration of the progressive pathology of the condition and of the experiments of Leser and others.

While splitting the aponeurosis has not been done in the acute stage, as suggested by the late Dr. Murphy in a recent communication,[47] the application of the principle 18 months ago in a fully developed case

of long standing (Case III) seemed to help materially in the improvement.

The reason for treatment, up to this point, remaining in the theoretical stage is obvious from the average history in these cases, *i.e.* injury, more or less prompt reduction and tight fixation, absence of the practitioner for a week or more, oftentimes in spite of reports as to pain, swelling and cyanosis. When the dressing is changed after the lapse of a week the fully developed condition is found.

Treatment from this stage onward has developed along two lines:

1. The relief of the contracture deformity by operation which consists in (a) the lengthening of the tendons of the contractured flexor muscles. This is by far the most popular operative method. In the lower forearm the tendons are lengthened sufficiently (one, two or more inches) to permit simultaneous full extension of the fingers, hand and wrist. The tendons are lengthened at slightly different levels to avoid massive adhesions, and are individually surrounded by Cargile membrane for the same purpose.

(b) The resection of both bones of the forearm so as to shorten them sufficiently to permit simultaneous full extension of fingers, hand and wrist.

These two methods merely rearrange the mechanical relations between the contractured muscle-tendon units and their bony points of origin and insertion. This relieves the deformity but can scarcely be credited with causing the return of voluntary activity in the damaged muscles. Moreover, if either of these operations be done, and the extremity is allowed to go without vigorous after-treatment, there is a slow but sure return of the deformity as the steady growth of the bones of the forearm again lengthens the distance between origin and insertion of the still cicatrized muscles. This actually occurred in Case I in the course of a year.

In the successful cases reported after these operations, there is always reference to the vigorous use of all the means of physical therapeutics over periods varying from weeks to months and even years, so that it is reasonable to inquire how much is due to the operation *per se* and how much to the after-treatment.

To repeat once more, the essential lesion consists in the change of muscle to cicatricial tissue. If this change involves every bit of the muscle, no treatment, operative or otherwise, can ever restore active motion to the damaged muscle. If the damage involves only a portion of the muscle, the remainder is potentially able to cause voluntary motion provided it can be freed from the handicap of the con-

tractured cicatricial tissue mingled with it. The problem then resolves itself into finding the best means of removing the cicatricial handicap.

It is difficult to see how either of these operations could act in that way. Moreover, if they do, why is there the necessity for prolonged systematic physical therapeutics afterward?

If the tendon of a normal muscle is lengthened, the functional value of the muscle is diminished and the range of motion is lessened in proportion to the lengthening of the tendon. The same principle must hold true in the damaged muscle, so that these operations would seem to diminish somewhat the potential value of such muscle as is still viable.

In the tendon lengthening operation there is an increased risk of infection because of the defective nutrition, and there is the chance of adhesions among the tendons.

In the bone resections a number of cases of non-union have been reported.

Because of the many disadvantages of the operative methods there has been evolved:

2. The relief of the contracture deformity by mechanical stretching combined with systematic physical therapeutics.

(*a*) Robert Jones of Liverpool [16] for years has advocated this method because of the greatly improved results he has obtained, with the avoidance, at the same time, of the risks of operation.

Sayre [21, 26, 29] in this country has repeatedly emphasized the value of the method.

His method consists in cutting from sheet iron or zinc a small splint for each digit. When the wrist is forced into complete flexion, and the fingers can therefore be fully extended, each finger is bound to its individual splint and so maintains complete extension. The wrist is freed and the patient told to work at extending the metacarpophalangeal joints. After a few days, when this can be done, a splint is bound on from finger tips to wrist, covering the previous finger splints and maintaining full extension. The patient now works at extending the wrist and when this is finally accomplished a third splint is applied over the others from finger tips to elbow and holds all the intervening joints in a straight line.

The splint is bent from time to time to increase extension at the wrist until it is complete, and is then left in place for weeks, until there is no tendency to recurrence of the contracture when all restraint

is removed. Finally a systematic course of massage is given until all the improvement possible is obtained.

This method is sound in principle because it overcomes the contractured cicatricial handicap by means of stretching and physical therapeutics, and leaves such muscle tissue as is still viable free to regain its full functional value.

However, the superimposing of rigid splints covers the fingers in such a way as to prevent inspection readily, and to prevent the use of massage, heat, passive motion, etc., in the early stages of the treatment.

The fingers are especially liable to develop pressure sores because of their defective nutrition and innervation and, therefore, they should be exposed for inspection. The early institution of physical therapeutics is certainly of great value.

These considerations led to the adoption of the apparatus and technic used in all but one of the small group of cases appended. This might be called—

(*b*) *The elastic traction method* of overcoming cicatricial contracture. (A method which may be adapted to overcome almost any type of cicatricial ankylosis or contracture.)

As may be seen by reference to Figs. 2 and 3, the essential feature lies in putting the traction of rubber elastic against the resistance of the contractured cicatricial tissue.

Its advantages are numerous:

The pull can be graduated to any degree suitable to the individual case, and can be varied by changing the number or tension of the rubber bands.

Just as soon as the contracture yields a little, the rubber takes up the give and keeps on pulling.

A moderate tension on the rubber bands will cause a prompt, steady, persistent, and practically painless stretching of the contractured tissues.

The child's attendant is readily taught to apply and adjust the brace, so that it may be removed once or twice a day for massage, etc., from the very start, so that inspection for pressure spots is a matter of routine twice a day. Visits to the surgeon need be only at infrequent intervals.

The details of treatment in all except the first of the group of cases appended, were as follows:

The brace was made on a plaster of Paris model of the forearm so as to fit smoothly. It was applied without lacing it so tightly as to interfere with the circulation.

Elastic traction was applied up to the point of moderate discomfort.

The apparatus was left on continuously except for two intervals of an hour each, morning and afternoon. During these periods, the whole extremity was immersed in hot water for twenty minutes, kept as hot as bearable by constant addition of hot water.

If nerve involvement is present the heat must be less and the attendant's hand should be used as a guide.

After the immersion, massage and vigorous passive motion were used, and, finally, attempts at voluntary motion were encouraged. It is remarkable how greatly this prolonged use of heat increases the stretchability of the contractured tissues even if only temporarily at first.

When the contractured tissues have been well stretched, so as to permit a good degree of passive extension of fingers and wrist simultaneously, the apparatus has been left off during the day so as to encourage active motion and use, and then worn during sleep to avoid recurrence of the contracture.

As the tendency to recurrence has disappeared the apparatus has been used less and less until it has finally been discarded. The child is systematically trained to use and develop all the muscles which have survived.

By either of the extension methods the contracture can be overcome so that the fingers, hand and wrist can be simultaneously fully extended, which accomplishes the same result as either operative method per se.

If, now, there is any viable muscle tissue left in the flexor group, it can be brought back into voluntary activity by the same methods of physical therapeutics as must always be used after operation to get the results.

If no viable muscle tissue is left, then voluntary motion cannot be restored by either method, and the only result is mechanical relief of the deformity. The time required for non-operative extension varies from a few weeks to a number of months, varying with the amount of cicatricial tissue and the length of time the contracture has existed.

The extension method, therefore, offers as much prospect of recovery as the operative method, and at the same time avoids the pain, risks and expense incident to operation.

Decompression applied to the flexor group of muscles by means of splitting the deep aponeurosis freely may prove to be a very helpful

procedure in the more severe cases, although at present the clinical evidence is insufficient to justify any conclusion.

Nerve injuries occur primarily or secondarily, in about 60 per cent. of the cases, as previously mentioned.

When there is simply a diminished activity of the nerve, no operative interference should be considered until the contracture has been overcome, because it has frequently been observed that during the process of stretching out the contracture, the symptoms of interference with nerve function also disappear (see Case II).

If, however, these symptoms persist after the contracture is overcome, the nerve or nerves should be explored in the fracture area and throughout their involvement in the cicatricial tissue, and such damage as is found should be repaired by appropriate means, suture, neurolysis. transposition, etc.

When the original injury has divided one or more nerves (and this, for reasons previously given, is seldom discovered promptly) operation is contra-indicated during the acute stage of the myositis and until any infected pressure-sloughs have been thoroughly healed. Then the damaged nerve should be repaired without further delay.

CASE I.—L. K., five years old. On May 5, 1906, he fractured the lower end of the right humerus.

One hour later the extremity was put up in a circular plaster splint. Soon there was great pain, swelling and cyanosis of the hand. Large blebs formed on the hand.

On the 7th day (May 12) the splint was split on two sides and lifted off. There was an abscess on the flexor aspect just below the elbow. Voluntary motion was lost in the fingers which were rigid. After dressing the abscess, the two halves of the splint were replaced and bandaged on.

At the end of four weeks (June 2, 1906) the splints were left off entirely. There was then a well developed ischæmic contracture. On the supposition that the paralysis was due to involvement of the musculospiral nerve by callus, exploration of the nerve was made and it was normal.

For the succeeding year massage, electricity, vibration, etc., were used with no result. The hand was useless. On June 24, 1907, he was brought for consultation. There was the deformity of fracture of the external condyle of the right humerus, and the scar resulting from exploration of the musculospiral nerve. The scar from the flexor abscess just below the elbow was 4x2 cm. The right forearm, wrist and hand showed typical main-en-griffe and the rigid fingers could not be extended actively nor passively.

The flexor muscles formed a rigid cicatricial mass, which prevented extension of fingers and wrist, and also complete extension of the elbow. The extensor muscles could be made to contract voluntarily but they caused no motion in the fingers because of the extreme flexion contracture. The hand was cold, and blue, and the skin was shiny. There were trophic disturbances of the finger ends, especially of the middle and index fingers. There was atrophy of the interossei, the thenar and hypothenar muscles.

On July 6, 1907, fourteen months after the injury, operation was done under ether. The median nerve, exposed by an incision through the cicatricial flexors, was found to be compressed, thin and white for a length of 5 cm. just below the elbow. A canal was made for it through the cicatrix and it was surrounded by Cargile membrane. The ulnar nerve, also exposed, showed less evidence of compression. It was treated as was the median. The wound was closed without drainage. The superficial flexor group was almost entirely cicatrized and scarcely bled when cut. The deep flexor group showed some remaining muscle substance. About 3 cm. were resected subperiosteally from the lower thirds of both the ulna and radius. The bones bled freely. The periosteum was so elastic that there seemed no redundancy when the bone ends were approximated. An aluminium ferrule was slipped over the ends of each bone beneath the periosteum to maintain good alignment, and the wounds were closed. The fingers, hand and wrist could be readily extended to a straight line and were put up in an anterior splint.

August 24 (7 weeks after operation) the splint was removed. There was firm union in each bone, with fusiform swelling over the aluminium ferrules. Fingers and wrist could be fully extended.

October 30, 1907 (3 months and 24 days). There was some return of flexion contracture of the wrist and fingers; and some action of the interossei. The thumb could be adducted and slightly flexed. The hand showed improvement in warmth, color and nutrition (nerve regeneration).

February 3, 1908 (7 months). More contracture deformity. Atrophy of the intrinsic muscles of the hand was much less marked. The trophic disturbances have disappeared. The thumb could be adducted, slightly flexed, and could grasp strongly. The little finger could be slightly flexed voluntarily. All the digits could be slightly extended voluntarily. The cicatricial flexor mass was less hard, and the elbow could be extended more fully than before operation. The swelling over the site of resection of the radius was entirely gone, but that on the ulna was still marked.

March 6, 1908 (8 months). The swelling on the ulna was much smaller.

The fingers were more freely movable, and could be slightly flexed by the long flexors. Extension was stronger. The intrinsic muscles of the hand were developing rapidly. The thumb had a strong grasp against the forefinger.

At this time the boy passed from observation.

This case shows that growth of bone gradually caused a reproduction of the deformity, as it must always do, unless the cicatricial mass is stretched and softened so that growth may equal that in the bones.

The great value of nerve exploration is indicated.

CASE II.—M. H., six years old. On June 20, 1911, he suffered a fracture of the lower third of the left ulna. Within two hours the forearm was put up in padded wooden splints firmly bandaged on from the elbow to the fingers. In an hour extreme pain developed, followed by great swelling and cyanosis of the hand and fingers. The pain was so severe as to cause delirium during which he bit the splint, his fingers, etc.

In spite of several reports to the physician of the progress of events, the boy was not seen until the fourth day when the dressing was removed and the fingers were seen to be rigid. Also there was a large slough and abscess on the flexor surface of the forearm below the elbow. After three weeks of daily dressings the abscess was healed. Meanwhile the contracture, which had been in evidence on the fourth day, rapidly developed to the typical attitude (Fig. 5). Nothing was done for the essential condition.

Toward the middle of August the mother noticed that a pin-prick, in the ulnar distribution in the palm, which was deep enough to draw blood, was not felt. Further investigation showed the whole ulnar area of the hand to be anæsthetic, and the median area to be hypæsthetic.

They then consulted one of our most competent surgeons who said it was a very severe case of Volkmann's contracture, that the only hope lay in shortening both bones of the forearm and that even operation held out but little prospect of giving a useful hand and forearm.

On August 16, 1911, he was brought to me with the above history. Examination showed a typical well-marked contracture deformity (Fig. 5). There was no active motion in the wrist or fingers. Flexion of the wrist and fingers could be increased passively but the rigidity almost completely prevented extension.

The site of the fracture in the lower third of the ulna could

be plainly made out, union was solid and the alignment was good. A hard mass extended from the point of union over to the radius, interfering with supination and pronation.

On the flexor surface of the forearm just below the elbow was the healed scar of the abscess, about 4 x 2 cm., and beneath and connected with it the whole group of flexor muscles was one hard rigid mass.

The entire area of ulnar nerve distribution in the left hand was anæsthetic. The median area was hypæsthetic.

The skin of the fingers was thin, shiny, and the hand was cold and cyanotic, the nails were cross-ridged, and there was atrophy of the intrinsic muscles of the hand.

It looked like a very severe case of contracture with complicating nerve lesions, and the prognosis seemed absolutely bad.

The disappointments following the operative treatment of Case I, had caused the theoretical evolution of the Elastic Traction Method previously described.

Treatment by this method was started August 20, 1911, with the brace shown in Fig. 3, combined with the various methods of physical therapeutics.

Within four days the contracture began to yield to the traction and from that time on progress was rapid.

On August 29 it was necessary to change the angle of the brace to get more extension. He was beginning to move the wrist and fingers, which could be passively extended beyond a straight lime simultaneously.

He was not seen again until October 7 (48 days after starting treatment), at which time the hand had become nearly normal in color, warmth, and sensation, and the intrinsic muscles had gained volume.

The cicatricial mass of flexors had softened remarkably, although they still restricted *active* extension of the wrist to slightly beyond a straight line. Passive extension could be carried almost to normal. The fingers could be moved with fair freedom. (The parents reported that within two weeks of starting treatment sensation had largely returned to the hand, the fingers were moving fairly freely, and that the color, warmth, etc., were much more natural.)

At the end of December, 1911, they reported him to be perfectly well.

On October 18, 1916, five years after treatment, the condition is as follows: The fingers and hand are normal in size, nutrition and sensation. All motions are free, strong and normal, except that the extension of the wrist is limited slightly (see Fig. 10). To passive motion the wrist extends further but there is a sense

of resistance not felt in the normal hand. He plays the piano and violin and recognizes no limitation in usefulness (Figs. 5, 6, 7, 8, 9, and 10).

This case demonstrates perfectly that the pathological lesions were not at all as serious as the clinical findings seemed to indicate, and that accurate prognosis is almost impossible at the start. Any form of operation, in this case, could only have prejudiced the result.

The fracture was unusually low and the muscle damage must have been chiefly from direct splint pressure.

Attention is also called to the very rapid improvement of complicating nerve lesions (which seemed very serious at the start) as the contracture yielded to the stretching.

CASE III.—G. H., four years old. On February 9, 1914, she fell and fractured the right humerus just above the condyles. Within two hours, under ether, reduction was attempted and the arm put up at a right angle with shaped wooden splints. The following day, under chloroform, the splints were removed and the elbow was held at much less than a right angle by adhesive plaster dressing. Within two hours great pain occurred together with marked swelling and cyanosis of the hand. The angle of the elbow was then made less acute. That night she had high fever and delirium. The following day the pain was less and the temperature was normal. On the fourth day after the accident she developed a temperature which, for ten days, ran between 101° F. and 102.5° F. Pus was then seen to ooze from the region of the wrist. Removal of the dressings revealed a large abscess on the ulnar side of the wrist and another just below the elbow on the flexor surface. Daily dressings were done and the elbow kept at slightly less than a right angle.

Three weeks after the injury the arm was placed in a sling. It was discovered that the elbow was stiff. Four weeks after injury it was noted that the hand was totally paralyzed. The mother had noticed that there had been no voluntary motion in the hand or fingers from the time of the accident.

The fingers did not stiffen or contract till toward the end of March, nearly seven weeks after the accident.

On April 8, 1914, two months after the accident, when she was first seen, the conditions were as follows:

She was a sturdy, well-nourished child, highly nervous from her recent experience.

The right elbow showed normal relations between the bony landmarks. There was a firm bony mass projecting forward

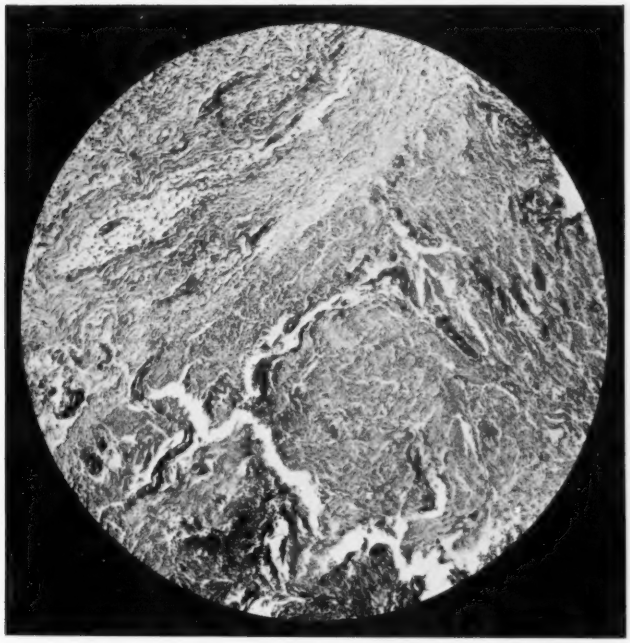

FIG. 1.—Photomicrograph of a section from the middle of the flexor group of muscles, about 4 cm. below the elbow in the median line in Case III. No muscle fibres appear, and the connective tissue is not disposed in an orderly manner.

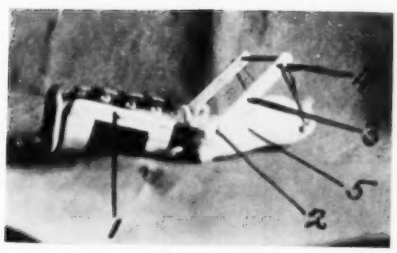

FIG. 2.—1, the sleeve portion of the brace extending from the elbow to wrist, made of steel and leather; 2, an adjustable joint so that the direction of the traction may be changed as improvement occurs; 3, adjustable offset; 4, projecting knob to hold the elastic loop running to 5, a pad to which the hand and fingers are bound when in full extension. This is done after the primary stretching is done as in Fig. 3.

FIG. 3.—This is the original brace made for Case II, applied to his arm five years after its primary use, just to show the wooden cylinder under the fingers, instead of the pad. This brace has no adjustable joint at the wrist like the improved one in the preceding figure. The brace originally reached from the wrist to the elbow, so that its present application shows the result of five years of growth in the forearm.

FIG. 4.—X-ray taken nine months after operation for ischæmic paralysis. 1, site of resection of the radius, showing the aluminum tube still in the callus; 2, site of resection of the ulna, showing the tube more distinctly and a larger callus. The perfect alignment of both bones obtained by using the tubes is clearly shown.

FIG. 5.—Case II. Taken just after the beginning of treatment, when there had already been some stretching of the contractured tissues.

FIG. 6.—Shows the easy natural position of the left hand and its normal size. Figs. 6 to 10, inclusive, were taken October 18, 1916, five years and two months after treatment began.

FIG. 7.—Shows power of spreading the fingers, complete recovery of the interossei.

FIG. 8.—Complete supination of hand and forearm, adduction of fingers and full abduction of the thumb.

FIG. 9.—Firm fist showing power of flexor muscles.

FIG. 10.—Extension of wrist, showing slight limitation on the left side. Passively the wrist can be fully extended. He plays both violin and piano.

FIG. 11.—Case IV. Showing original position.

from the humerus just above the elbow and just to the inner side of the median line of the humerus.

The scars of the old abscesses were present on the ulnar side of the wrist and on the flexor surface of the forearm, just below the elbow, to which was adherent the cicatricial mass of the flexor muscles.

There was the typical deformity of Volkmann's paralysis.

Motion. Active. The elbow could be flexed to 45°, the limitation seeming to be due to bony contact, and extended to 145°, the limitation being due to the contractured flexors. The wrist, starting from its position of marked flexion contracture, could be very slightly flexed and extended. The fingers showed the slightest suggestion of flexion and extension. The thumb could not be moved. The interossei showed no action. Passive. Elbow as above. The wrist could be fully flexed: could be extended not quite to a straight line provided the fingers were allowed to flex completely. The fingers could be fully flexed: could be extended about three-fourths straight with the wrist fully flexed, and about one-third straight when the wrist was held in extended position. The thumb clung closely to the index finger and could be abducted with difficulty. Pronation of the forearm was normal. Supination about three-fourths normal. There was atrophy of the intrinsic muscles of the hand. Sensation. There was anæsthesia in the distribution of the ulnar nerve to the hand and fingers. There was hypæsthesia in the distribution of the median nerve to the hand and fingers. Radial sensation was normal. The flexor muscles below the elbow formed a firm, hard mass, smaller than normal and very adherent to the overlying scar.

Treatment was started on April 13, 1914. On May 27 (6 weeks later), the fingers, hand and wrist could be simultaneously extended (passive motion) almost to a straight line. There seemed to be very slight improvement in ulnar sensation, but no improvement in active motion.

The evidences of serious nerve damage, with the history of motor paralysis at the time of the accident, together with the bony projection just above the front of the elbow were strong indications for exploration.

On July 14, 1914, exploration was done in another city, after which the following information was received. A long anterior incision exposed the bony prominence which was a spicule projecting from the lower end of the upper fragment of the humerus. Further dissection showed that this spicule had pierced the median nerve and severed about half of it. Everywhere, at and below the elbow, there was dense scar tissue. The damaged median

nerve was sutured without removing the end-bulb on the proximal stump. The spicule of bone was removed. The extremity was dressed with the elbow at a right angle.

November 15, 1914. The elbow could be flexed to 45° and extended only to a right angle. The scar of the incision was keloidal in character in spite of healing by primary union. There was no change in the median nerve area.

May 8, 1915. The median nerve had shown no signs of regeneration. There was complete atrophy of the intrinsic muscles of the hand. The skin was thin, shiny and cold. The nails showed transverse ridges. There was no improvement in the mobility of the elbow.

May 10, 1915. Operation by the author.

The ulnar nerve was exposed behind the inner condyle and down into the forearm. Behind the condyle it was much swollen and congested for a distance of 2 cm., above and below which it was normal in appearance. It was lifted from its groove and transplanted into the subcutaneous fat in front of the condyle, to relieve it from the pressure of the condyle which had been displaced backward at the time of the accident, and had caused the neuritis. For a distance of 6 cm. below the condyle there was fairly good muscle tissue which contracted feebly to the faradic current. This gave a hopeful aspect to the prognosis. The wound was closed with silk.

The median nerve was explored through the old incision. There was dense fibrous tissue everywhere. The deep aponeurosis of the forearm was very thick and showed the silk sutures of the previous operation. The division of the aponeurosis exposed the proximal bulb of the median nerve to which everything around was quite adherent. From the lower end of the bulb ran a thin cicatricial cord downward to the distal part of the nerve.

Transverse sections were made above and below until good nerve bundles were encountered (about 2 cm. in all being resected) and then the ends were apposed by means of silk sidehitch sutures. Complete apposition was obtained without strain on the sutures. The junction was surrounded with Cargile membrane.

The deep aponeurosis of the forearm was split downward for a distance of 7 cm. below the elbow and left open for decompression. The flexor muscles (except for those near the inner condyle previously mentioned) seemed completely fibrous. A small section was removed. (Fig. 1.) The skin was closed with silk and the arm put up with the elbow at slightly less than a right angle.

July 1, 1915 (52 days after operation). The color and temperature of the hand and the trophic condition of the fingers and nails were much improved. The atrophy of the intrinsic muscles of the hand was unchanged.

There was voluntary flexion of the wrist for 30° from the straight line. There was extension through the same arc. There was definite but slight flexion of all the fingers. The cicatricial mass below the elbow was much softer and motion occurred in it when attempts at flexion were made.

May 12, 1916 (1 year after operation). The wrist could be actively flexed and extended through an arc of 90° (of which 30° was back of a straight line) and could be adducted easily. The fingers could be extended almost to the straight line with the wrist straight, and could be flexed actively but with very slight power. Extension was followed by a flexion produced by the natural spring-back of the contractured tissues, but in addition there was a very slight positive flexion. The fingers could be ab- and adducted fairly well and the thumb very slightly. The flexor group below the elbow had changed from the old indurated mass to one of soft consistency, which was, however, much smaller than the normal group of muscles should have been. There had been no improvement in motion at the elbow. Extension beyond a right angle seemed to be limited by a bony contact. Supination was very limited, the hand being held in the almost fully pronated position.

Stereoscopic X-ray pictures of the elbow showed a bony outgrowth from the posterior border of the capitellum which interfered with extension beyond a right angle, and probably interfered with supination.

Sensation is almost normal in the entire hand.

July 13, 1916 (14 months after operation). Pinpricks were accurately localized everywhere in the hand and fingers. There was hyperæsthesia in the median area, indicating the active but not yet complete regeneration of the median nerve. All the motions noted in the previous examination were of greater range and strength. The bony growth from the capitellum could be readily felt and the head of the radius came up against it with a click and stopped extension at a right angle. Mobilization of the elbow should be the next step.

After the first few months of treatment the outlook seemed nearly hopeless, but perseverance in treatment, stage by stage, has led to the improvement of the last few months which makes the prognosis most hopeful.

Courage for continued effort was given by the known presence of viable muscle at the upper ends of the flexor muscles near the

inner condyle, and the early evidences of beginning recovery in the ulnar and median nerves after operation in May, 1915.

For the results so far obtained too much credit cannot be given to the intelligent and absolute devotion of the trained nurse who has been in continuous charge of the case.

CASE IV.—Margaret D., eight years old. Toward the end of June, 1914, she broke both bones of the left forearm at the middle. After reduction wooden splints were used for two days and were then replaced by a circular plaster splint. Within a few hours there occurred severe pain, with swelling and cyanosis of the fingers and hand. She was awake and cried all night. On the second and third days the swelling and cyanosis were very marked and then gradually subsided.

On the seventh day the cast was removed. The fingers were then beginning to flex. There was a slough on the flexor surface a little below the elbow, and a deep ulcer in the hypothenar muscles, which was two months in healing. The contracture of the fingers became steadily worse.

September 21, 1914. The patient was a healthy, well nourished girl.

The left hand and forearm showed the typical well marked deformity. (Fig. 11.)

There was some bowing forward of both bones in the middle of the forearm and there was a hard mass between them. The wrist was markedly flexed, had no voluntary motion, and very slight passive motion. Attempts to extend the wrist flexed the fingers more tightly. The fingers had a very slight degree of active flexion. The skin was thin and shiny. The sensations of the hand and arm were normal except for hypæsthesia of the ulnar side of the little finger (perhaps resulting from damage to the ulnar filaments in the old abscess and scar of the hypothenar eminence). The elbow could be actively flexed and extended completely. Treatment was started September 25, 1914.

November 16, 1914 (8 weeks). The wrist was extended well backward of the straight line although the fingers flexed moderately at the same time. Active motion of the fingers was much improved and the interossei were beginning to act.

The flexor group in the upper forearm could be felt to contract actively but the resulting motion was slight because of some obstruction at the site of fracture.

The thumb did not move but remained close to the index finger. Sensation was still deficient on the ulnar edge of the hand and little finger.

During the spring of 1915 she died of what was said to have been tubercular meningitis before there had been further opportunity for her to come to town for examination.

SUMMARY

Experimental work and clinical observation point to *traumatic myositis* as the fundamental condition in causing Volkmann's ischæmic contracture.

The pressure causing the muscle disorganization is both internal and external: Internal, because the flexor muscles are firmly confined by their envelope of aponeurosis and bone, and, when injured, have no chance to expand to relieve the pressure due to extravasation and œdema. External, because of tight dressings or the position of acute flexion at the elbow.

The result of the pressure is to cause degeneration of the muscle substance and its replacement by connective tissue, the contraction of which causes the typical deformity.

The damage to the muscle may be very slight, it may be complete, or it may be of any grade between these two extremes, and it is impossible clinically to determine at an early time just how extensive the damage is. (See Case II.)

Complications.—Pressure sloughs and abscesses are common on the ulnar side of the wrist and on the flexor prominence just below the elbow. When present, these abscesses usually burrow to the deeper structures, heal very slowly and add greatly to the cicatricial rigidity. Thomas [27] found these present in 37 out of 107 collected cases.

Nerve injury is purely a complication. It occurs in about 60 per cent. of cases. It may be *primary* as a result of the accident and may involve one or all of the nerves partially or completely. However, the ulnar and median nerves are the ones usually involved, the musculospiral escaping. It may be *secondary* and by far the larger portion of the 60 per cent. belong in this class. It may occur early, as the result of the pressure of the swollen muscles, or, more frequently, later as the result of cicatricial constriction. The ulnar and median nerves are most often involved and are usually constricted within a short distance below the elbow.

Interference with function is usually only partial, but it may be complete.

The usual clinical history is: Child of 1 to 14 years of age. Fracure in elbow region (general term for neighborhood) put up in tight dressing, or in extreme flexion of the elbow, and usually left untouched for from 4 to 10 days. Very soon, severe pain, swelling and cyanosis of the hand, often blebs, sometimes rise of temperature. The pain and swelling gradually subside and the rigid flexion contracture develops early or late according to the case. The deformity, once developed, is

characteristic. There is moderate pronation of the forearm, marked flexion of the wrist, extension of the metacarpo-phalangeal joints, marked flexion of the remaining finger joints. The thumb is often firmly adducted. There may be some active motion in the flexors but it is always very slight. Attempts to extend the wrist passively cause marked flexion of the fingers; full flexion of the wrist permits extension of the fingers. The flexor group of muscles and tendons stand out as a hard, firm, rigid mass, obviously the cause of the resistance to motion. The feeling of the mass and its resistance to motion do not indicate just how complete the cicatricial change is. (See Case II.) The hand is usually cold and blue from deficient circulation, and these symptoms are aggravated if there has been nerve damage. Nerve damage is indicated by partial or complete loss of sensation, by motor paralysis (which can usually be distinguished only in the intrinsic muscles of the hand since the flexor muscles in the forearm have lost their function from the myositis), and by trophic disturbances also most noticeable in the hand and fingers.

Prognosis should, as a rule, be unfavorable. Inasmuch as it is impossible to determine clinically the exact amount of damage, an accurate prognosis cannot be given until the reaction to proper treatment has been watched for a time.

Treatment.—Prophylactic: In children from 1 to 14 years, in injuries about the elbow region, tight dressings should be avoided, as well as extreme angle of flexion at elbow. In all injuries of this type, the medical attendant should be in constant touch, so that if undue pain, swelling and cyanosis occur, prompt measures may be taken to prevent the full development of the lesion.

Immediate: All dressings should be removed, the limb elevated, and gentle massage and passive motion given while the site of fracture is steadied and supported by hand. If in spite of these measures the swelling and cyanosis increase, one should attempt decompression of the flexor muscles by splitting the deep aponeurosis longitudinally, either subcutaneously, or together with the skin if that is œdematous and shiny. Sterile dressings and a light supporting splint with the elbow at right angle (or more) should be applied.

When the danger of the ischæmic lesion is passed the fracture may be treated as best the circumstances permit.

Late: Operation either lengthens all the tendons of the contractured muscles to permit simultaneous extension of the fingers, hand and wrist to a straight line, or shortens the bones sufficiently to attain the same result. The risks of operation are increased by the poorly nourished

condition of the extremity, and the growth of the bones will gradually cause recurrence of the deformity (see Case I). Lengthening the tendon of a muscle lessens its efficiency.

After an operation has mechanically relieved the deformity, the real work of rehabilitation must be done by a prolonged course of physical therapeutics. Therefore it would seem preferable to avoid the trouble and risk of operation by employing the method of mechanical overstretching of the contractured tissues. This method combined with physical therapeutics, obtains results which for promptness and quality are as good or better than those obtained by operation.

This may be accomplished by the Jones method of rigid splints, or by the method preferred by the author which may be called the elastic traction method.

Cases may make a full recovery in a few weeks (Case II) or may require months or years before the best result is obtained (Case III). Nerve injuries cannot be operated upon during the actue stage of the myositis.

If nerve has been injured primarily at the accident (and this is difficult to determine as a rule) exploration and repair should be done shortly after the subsidence of the acute stage.

When the symptoms of any nerve damage persist after the deformity has been overcome by stretching, exploration should be made, and appropriate treatment carried out. Usually the compression is just below the elbow, so that exploration should first be done there and carried upward or downward as conditions indicate. Where there has been fracture of the inner condyle the ulnar nerve should be explored behind it, if there are symptoms of interference with ulnar nerve function. (See Case III.)

Finally, persistence in treatment is the one hope of success in the severe cases.

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GUNSHOT INJURIES OF THE PERIPHERAL NERVES AND THEIR TREATMENT*

By Hermann Fischer, M.D.
of New York

On account of the far-reaching consequences to the patient the treatment of injuries of the peripheral nerves has always been an important problem to the surgeon.

In peace times the experience of the individual surgeon has been very limited for obvious reasons. During the first two years of the great European War, the number of nerve injuries has been appalling and the treatment of nerve wounds constitutes one of the most urgent problems facing the surgeons of the belligerent nations.

During my work in Germany as chief surgeon of a Reserve Lazaret in Oppeln in lower Silesia, from October, 1915, to April, 1916, there were among 365 cases of wounds of the upper and lower extremities, 15 cases of paralysis of one or more of the peripheral nerves. Of this number 8 patients improved so much under massage and electrical treatment that surgical interference was deemed unnecessary. In 7 cases operative interference was indicated.

Case I.—E. P. was wounded on November 12, 1915, by a rifle bullet in the right thigh. Wound of entrance 10 cm. above the external condyle of the femur; wound of exit 8 cm. above internal condyle. Both wounds were healed. There was a complete paralysis of all the flexor and extensor muscles of the leg.

The patient was treated by massage and electricity without any result for eight weeks.

Operation (February 2,1916).—The sciatic nerve was isolated and it was found that 3 cm. below its bifurcation the peroneal nerve was deeply imbedded in a dense scar tissue. After removing this by careful dissection, the peroneal nerve presented a spindle-shaped scar 2 cm. in length. This scar was excised and the nerve stumps carefully sutured with four fine silk sutures which only passed through the perineurium. The suture was surrounded by a cuff of fat tissue and the skin wound closed.

Case II.—I. G., wounded near Dünaburg on September 9, 1915, by a rifle bullet which penetrated the upper arm just below the anterior axillary fold. When he entered the hospital his

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wound had healed but he showed all the symptoms of a complete median and ulnar nerve paralysis.

As the wound was received about three months before and there was no sign of improvement, operation was decided upon. Both nerves were found completely severed and their stumps imbedded in dense scar tissue. The median nerve showed a large neuroma at the proximal stump.

After excision of the scar there was a defect of 2½ cm. in the median and a defect of 2¾ cm. in the ulnar. The stumps could, however, be approximated without much trouble by 4 sutures through the perineurium. Both sutures were covered by a cuff of fascia, taken from the fascia lata of the thigh.

CASE III.—T. D., wounded on August 17, 1915, by a rifle bullet in right shoulder. The wound had healed. Right after receiving the wound, his entire right arm was paralyzed.

Examination showed injury involving median, ulnar and radial nerve.

Dissection of nerve just below margin of pectoralis major revealed all three nerves imbedded in a large and dense mass of cicatricial tissue and completely severed.

The isolation of the different nerve trunks was very tedious and difficult. The proximal stumps of the median and ulnar nerves each showed a large neuroma. The scar tissue was incised and the nerve stumps sutured. Although there was a defect of 6 cm. in the median and a defect of 3 cm. in the ulnar and radial, suture was accomplished by approximation of the arm to the thorax. Each nerve suture was surrounded by a cuff of transplanted fascia lata.

CASE IV.—W. N., wounded near Brest-Litovsk on August 22, 1915, by rifle bullet in upper arm. Paralysis of ulnar and median nerve.

Operation (October 29, 1915).—Incision along inner border of biceps. Ulnar and median nerves were imbedded in cicatricial tissue almost as hard as cartilage. Both nerves were completely severed in the middle of the arm, the bullet having passed from above inward to below outward. The proximal end of the ulnar nerve showed a distinct large neuroma whereas the median nerve was more or less flatted at its proximal end.

Dissection was difficult, the brachial artery being firmly adherent to the median nerve posteriorly. After excision of the nerve-scar the diastasis between the proximal and distal nerve stumps exceeded 5 cm. A neuroplasty was done by deflecting a flap of nerve-tissue from above downward and suturing it to the distal stumps. In order to separate the nerves from extensive scar tissue in the underlying muscles which could not be removed, a large

flap from the fascia of the brachialis anticus was deflected and sewn to the muscular scar tissue below the nerves.

The belly of the biceps was carefully sewn over the nerves and the skin incision closed.

CASE V.—S. K., wounded on September 9, 1915, by shrapnel in left thigh. Wound of entrance posteriorly in lower third of left thigh, wound of exit on inner side of femur a little further down. Peroneal paralysis.

Operation (November 11, 1915).— On exposing the sciatic nerve it was found that the same had been button-holed by the bullet just above its bifurcation. The nerve fibres of the tibial were fairly intact but the fibres of the peroneal were covered and bound together by scar tissue. A neurolysis after Stoffel was done which was not very difficult to accomplish, and the individual fibres of the nerves were thus freed from scar tissue.

CASE VI.—A. J., wounded near Brest-Litovsk, August 29, 1915, by rifle bullet 2 cm. below the knee-joint near the head of the fibula. Peroneal paralysis.

Operation (November 3, 1915).—The peroneal was severed just 1 cm. above its division into its muscular branches.

In this case an autoplasty was tried as it was evident that the nerve stump after excision of the scar could not be reunited. For this purpose the proximal stump of the peroneus was split, one-half cut off and implanted between the stumps. One-half of the distal end of the transplant was united with the distal end of the external peroneal, and the other half with the deep peroneal. A flap of fascia from the soleus muscle was deflected anteriorly and sewn over the graft. The wound was closed.

Unfortunately an infection occurred and the skin wound had to be opened and drained.

CASE VII.— A. Y. fell during the winter battle in the Carpathians in 1914 and injured both legs, a munition wagon passing over him. A splint was applied in a field hospital. When this was removed later on, he showed a peroneal paralysis of both legs. The X-ray pictures of this case were interesting as they showed a large osteoma that had developed in the biceps-tendons of each leg. It was thought possible that these bony masses might have been responsible for the paralysis of the nerve through pressure.

Operation showed that both nerves were almost completely destroyed for a distance of about 4 cm. on the right and 5 cm. on the left side, a thin thread of tissue only being left which connected the proximal and the distal stumps. These were reunited by a nerve plastic.

The operations performed in our seven cases were, to sum up: In three cases nerve suture; in two neuroplasty; in one neurolysis after Stoffel; in one auto-grafting. Unfortunately, I am not able to report on any end-results.

When I left Germany the cases had been operated upon only a short while before and none of them had shown any symptoms of returning sensation or muscular power. Nevertheless, I thought it might interest you to hear how German surgeons try to solve the question of curing paralysis of the peripheral nerves, and for this reason allow me to speak to you about the work that is being done in Germany along these lines and the results that have been achieved so far.

Types of Injuries.—Gunshot injuries of the peripheral nerves show a very varied picture. The direction in which the bullet is fired and the position of the limb at the moment of impact will, in a large measure, determine the amount of destruction. Those cases in which the bullet struck the nerve at an acute angle to its long axis, show the greatest amount of destruction of nerve substance as our fourth case showed. In other cases only individual fibres are destroyed when the bullet grazes the nerve.

In the present war perforation of a large nerve is not rare, on account of the small caliber of the modern army rifle and the velocity of the bullet (Case V), the bullet in these injuries apparently pushing the individual fibres apart. In a certain number of cases the nerve itself is not injured at all by the bullet, but simply contused, directly or indirectly, by the passage of the ball through the tissues. Particles from shells or bullets or spiculæ of bone, often smaller than a millet seed, may become imbedded in the substance of the nerve, causing, besides the palsy, unbearable neuritic pain. A scar that develops after a wound may produce a secondary paralysis by pressure, the nerve having escaped the bullet.

The nerves most frequently affected are the radial and the ulnar, then follow in order of frequency the median, the peroneal, the sciatic and the brachial plexus.

Diagnosis.—The diagnosis of a nerve injury is generally not very difficult. There are, however, cases in which injuries of the extremities are associated with paralysis of the affected limb, in which an actual nerve injury has not taken place. I refer to those cases, where the shock of the injury has induced a functional paralysis of a part or a whole limb. Hysterical phenomena may also appear in the form of contractures or hyperæsthesias, or hemiplegia. To distinguish between these conditions it is necessary to remember that hysterical paræsthesia or anæsthesia will never follow the anatomical distribution of a peripheral

nerve, and in hysterical anæsthesia the skin is moist and sweaty, while in severe nerve injuries the skin is cold, dry and scaly. The presence or absence of reflexes is also of great importance. They are absent in true paralysis due to nerve injuries. Generally speaking the functional paralysis can be differentiated with little difficulty, if the patients are properly observed and neurologically examined.

The diagnosis of the actual injury which a nerve has sustained, however, is very difficult and in a fair number of cases impossible. With all our known methods of neurological examination we are unable to differentiate between a contusion, a partial severing or a complete break in the continuity of a nerve trunk, for we are apt to obtain a reaction of degeneration in all three conditions. This uncertainty in the diagnosis has been the causative factor of the discrepancy of opinion among neurologists and among surgeons as to the indication of operative interference, and especially as to the time when conservative treatment should be abandoned and an operation advised.

Foerster, of Breslau, with whom I had the opportunity to discuss this question in relation to my own material, is conservative as to time. He advocates operation if after 4 to 6 months no improvement has shown itself and the galvanic reaction grows weaker. Spitzy, Wilms and other surgeons advocate early operation for the reason that the diagnosis of the extent of the actual nerve injury is so very uncertain, and because the operation itself is practically without danger.

In fresh cases, where on account of the nature and the seat of the injury a complete division of a nerve is suspected and where there is no infection, a primary suture will always give the best results. If there is doubt as to a complete separation of the nerve, we may wait for a few weeks.

If, however, on electrical examination, the galvanic reaction becomes weaker and slower, the nerve should be laid bare and inspected. Cases in which the injury dates back longer than 2 to 4 months ought to be operated upon, also those cases in which only a slight improvement has taken place. This is especially imperative since it is known that such excellent results are achieved after Stoffel's method of neurolysis in intraneural scar tissue. There are cases on record where, after the excision of intraneural scar tissue, with freeing of the individual nerve fibres from pressure, the nerve function has returned after a few hours. I will touch upon this point later on in detail.

Before I proceed to discuss the different operative procedures I will dwell upon the histology of nerve repair, the study of which,

especially in the last ten years, has guided the surgeon, and has put the treatment of nerve wounds on a more rational basis.

Through the study of Edinger, Buendner, Bethe, Cajal, Ranvier, and Doinikow, we know that restitution of the nerve is possible only when the central end can send out new fibres to meet the peripheral stump.

When a nerve has been severed it will be seen that after a very few hours, the divided axis cylinder will pour out a peculiar fluid substance in the form of droplets. In their endeavor to reach the peripheral end they grow out into fine threads which immediately meet the resistance of coagulated blood and young connective-tissue cells, interposed between the divided ends. As soon as these fine threads meet with this resistance they are deflected from their course towards the periphery and bend back towards the brain or deviate laterally, producing well-known and characteristic pictures. By this process the familiar end neuroma is formed (Figs. 1 and 2).

This irregular and seemingly aimless protrusion of threads will stop immediately, as soon as some fibres of the interrupted nerve-tract are encountered. With the help of the cells of Schwann the degenerated peripheral nerve trunk is comparatively quickly neurolized by the new fibres growing into it from the central stump. New marrow-sheaths are formed and the nerve is completely regenerated.

To sum up: *The central ganglia cells push out new nerve fibres as long as there is no resistance. Resistance (i.e., scar tissue) deflects the new nerve fibres. The nerve is regenerated by those fibres which reach the cells of Schwann, left over in the peripheral degenerated nerve.* From these histological facts two operative indications are deduced.

1. To remove the resistance as thoroughly as possible.

2. To pave the way for the new fibres to reach the peripheral stump (Edinger).

Methods of Operation.—In fresh, uninfected wounds of the extremities with injuries of nerves, the suture of the stumps is the procedure of choice. The nerve stumps must be very carefully handled with small pointed forceps, and care should be taken to grasp the perineurium only. The nerve stumps must not be rotated around their long axis in order to reunite the stumps of the individual fibres. Three to four sutures are sufficient. The suture material may be finest silk or catgut. Some surgeons warn against silk on account of the danger of an intraneural scar formation, to which silk is apt to give rise more frequently than catgut. On the other hand, catgut is not as firm and is quickly absorbed. As the suture should only be put through the

perineurium, without entering the nerve substance proper, I think this danger of scar formation is overrated.

Under the present condition of warfare the cases can rarely be operated upon immediately. The surgeon will always be confronted by cases in which more or less extra and intraneural scar tissue is present. In these all cicatricial tissue should be carefully excised. The end neuroma has to be removed until normal nerve fibres are seen on the cross-section of the nerve. Defects of 2 to 2½ cm. can usually be overcome. If the defects are larger and the nerve defect is near a joint, flexion of the limb will help approximation of the stumps.

In cases in which there is no complete division of the nerve there is found a spindle-shaped swelling of varying extent of the nerve itself. Here it is sometimes difficult to determine whether the nerve fibres are entirely or only partially destroyed. This spindle-shaped thickening is the so-called intraneural scar. It occurs in nerves that have been contused and pressed upon by a bullet or a splinter of bone. The perineurium of the nerve is injured, causing a hemorrhage around the nerve. In the substance of the nerve itself individual fibres may be torn and there also occur hemorrhages in the intraneural connective tissue. *This intraneural scar tissue envelops the individual nerve fibres and compresses them.*

In such cases the removal of the scar tissue around the nerve is not sufficient. Here an intraneural neurolysis (Stoffel, Heile, Hezel) is necessary to re-establish conductivity.

In order to remove the perineural scar the normal perineurium, proximally and distally from the scar, is carefully incised and lifted from the nerve with fine forceps. This enables one to get into the right plane of tissue. The incision is now carried into the scar and by blunt dissection the cicatrix is removed. This procedure is usually simple. The excision of the intraneural scar is a little more difficult. It is best to start again a little beyond the thickening of the nerve and, with a fine knife isolate a nerve fibre and follow it through the scar, completely freeing it from adherent tissue. The rest of the nerve fibres have to be treated in the same fashion, so that at the end of the operation the nerve is split up in its component " cables " (Figs. 3–7).

According to Stoffel, intraneural scars of 2 to 4 cm. length can thus be removed with comparative ease. When, however, the indurated tissue measures 6 to 8 cm., the tracing of the individual fibres is sometimes impossible. Fortunately these cases are rare.

Heile has recommended injections of sodium chloride solution into the intraneural scar, thereby facilitating the isolation of the individual

fibres. Von Hofmeister uses novocaine-adrenalin solution for the same purpose.

A thorough and special knowledge of the topography of the nerves is essential to good results. Most important are those fibres which convey motor-impulses and these should be freed as thoroughly as possible.

For instance, if we have to deal with a scar in the peroneal nerve, Stoffel recommends to first free the fibres leading to the tibialis anticus muscle. These are situated laterally and run close to the biceps muscle. After that the fibres of the extensor digitorum longus and hallucis longus and further on the fibres of the peroneal muscles are freed, this last bundle lying in the dorso-mesial aspect of the nerve.

In the median nerve we have to be especially careful to free the scar from its posterior surface, because here lie the most important motor fibres.

For want of space I cannot here describe the inner topography of the nerves. Those who are interested in this topic are referred to the publications of Stoffel.

After all fibres have been freed the nerve is ensheathed. Stoffel uses for this purpose calf arteries prepared after Foramitti.

The results which have been obtained by this endo-neurolysis have been surprisingly quick and good. Stoffel, Lange and Trumpp report that after neurolysis complete restitution can occur in two to three months.

It is, therefore, advisable never to resect an intraneural scar, before one has made sure by neurolysis, whether the fibres are really completely divided. Sometimes only certain fibres are divided whereas others have escaped. In such cases resection and neurolysis should be combined.

After the resection of the scar tissue, the defect in the nerve may be so large that suture of the stumps is impossible. Under such conditions other methods must be used. These are: (1) *Tubulization;* (2) *neuroplasty;* (3) *nerve-grafting.*

Tubulization.—Vanlair was the first to suggest that nerves might regenerate, if a path was provided along which the new fibres developing from the central stump might pass to reach the distal part. He, therefore, suggested placing the nerve stumps in tubes. Kirk and Lewis have recommended forming these tubes from fascia which is accomplished by free transplantation. Experiences, however, have shown that new nerve fibres do not grow into empty spaces and the fascia tubules are liable to contract and form scar tissue.

Harrison and Edinger proved that from pieces of spinal cord immersed into serum or into agar, new nerve fibres grow out into the medium. This can be seen and demonstrated under the microscope.

After a series of experiments Edinger finally worked out a practical method. He filled calves' arteries of different length with agar and had them sterilized. Ludloff was the first to use them in his nerve operations. They are now manufactured wholesale by large firms in Germany which also take the responsibility for their absolute sterility. These prepared arteries are enclosed in hermetically sealed glass tubes. The ends of the artery are closed by a ligature in order to prevent the agar from leaking out. Before use they are sterilized once more for 15 minutes, the tubes are then allowed to cool off, because the agar must be in a semi-solid state.

The scar in the nerve is excised in such a fashion that a few millimetres of scar tissue are left on both stumps. A thread is tied around this end *still inside the scar tissue* and with a needle pushed through the wall of the artery far enough from its end to enable one to pull the stump of the nerve into the agar-filled artery. The nerve is now fixed by a perineural suture to the end of the artery. The artery is then incised, at the site of the thread, and the nerve pulled out, the scar tissue cut off with a sharp knife and the nerve dropped back into the arterial tube, without handling the freshened stump. The little incision in the wall of the artery is closed by a suture. One has to endeavor, of course, to bring the ends of the nerves as closely together as possible.

Ludloff and Hasslauer had operated upon 14 cases up to February 15, 1916, by this method. Defects of 5 cm. to 20 cm. had been bridged. In all these cases, after 2 to 3 weeks, certain phenomena of regeneration showed themselves. The areas of anæsthesia became smaller and in a case where 10 cm. of the tibial nerve and 8 cm. of the popliteal nerve had been removed some muscular movement and the plantar reflexes returned sixteen days after the operation.

The improvement continues for some more weeks, but then follows a period of slow progress, this is obviously caused by the slower recuperation of muscles and joints.

Six to seven months after the operation there are still found on examination some difference in the volume of the muscles and some disturbance of sensation.

The Edinger method has been tried by numerous surgeons who also reported satisfactory results. There are undoubtedly some advantages of this method over the old suture and also over the newer methods of neuroplasty and grafting. When I left Germany the method had gained favor with many surgeons, but unfortunately I cannot supply

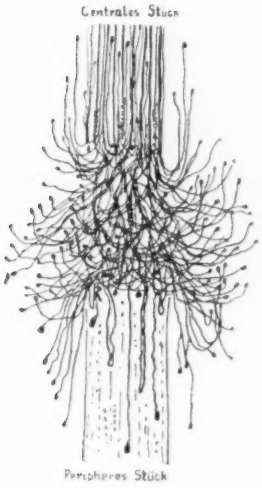


FIG. 1.—After Cajal.

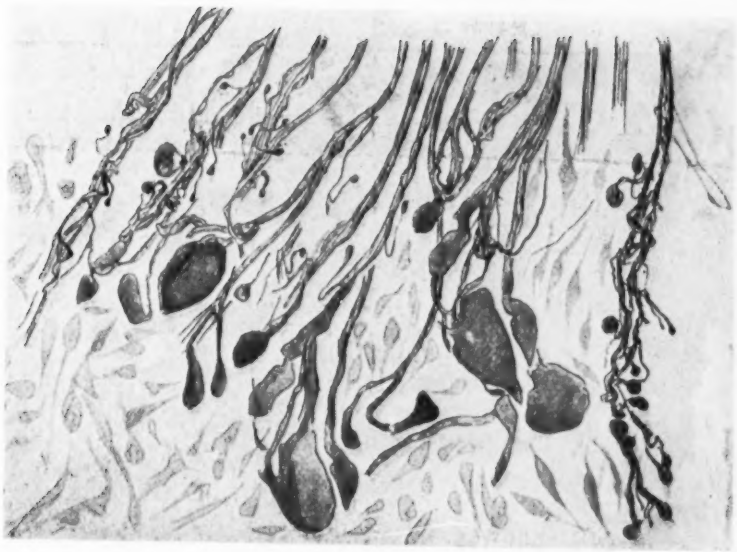


FIG. 2.—After Cajal.

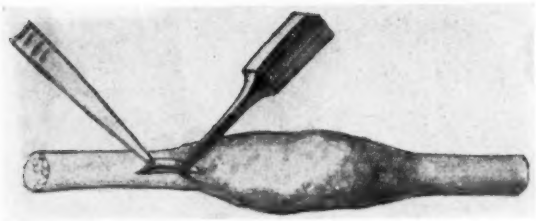


FIG. 3.—After Stoffel.

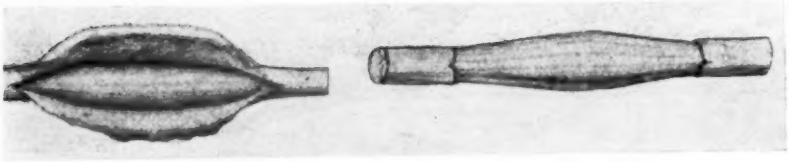


FIG. 4.—After Stoffel.

FIG. 5.—After Stoffel.

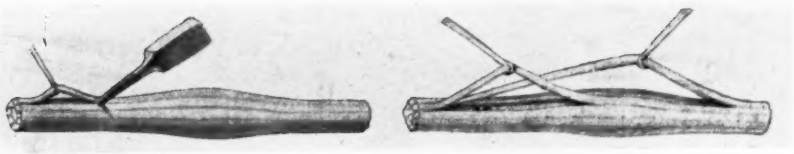


FIG. 6.—After Stoffel.

FIG. 7.—After Stoffel.

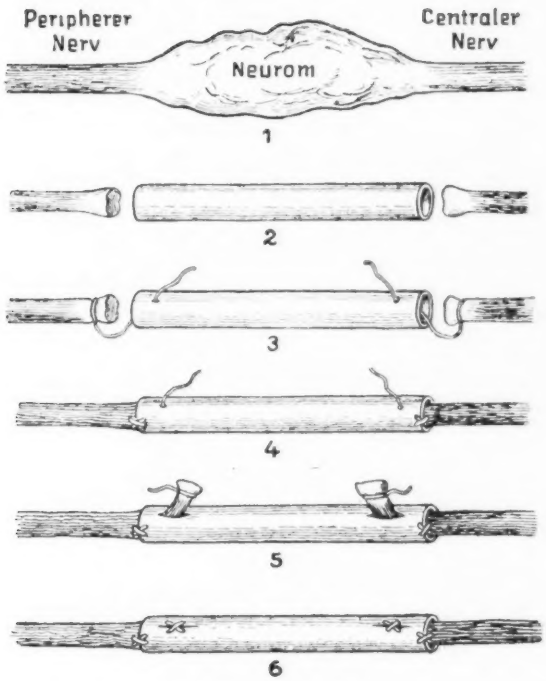


FIG. 8.—After Ludloff.

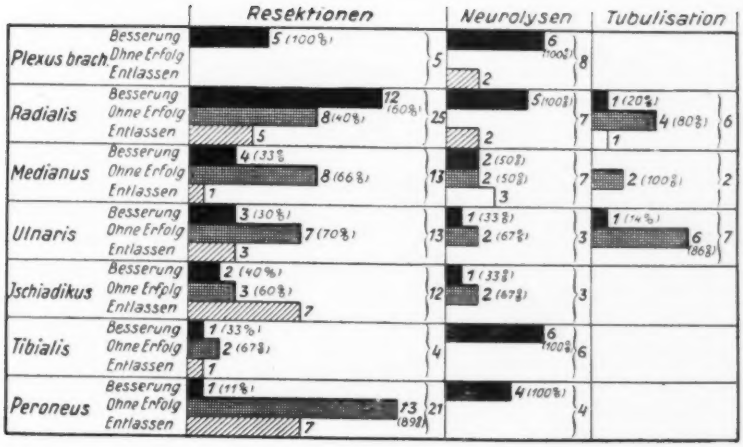


FIG. 9.

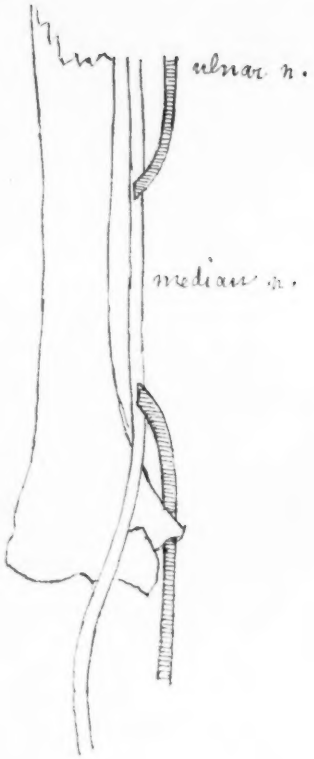


Fig. 10.

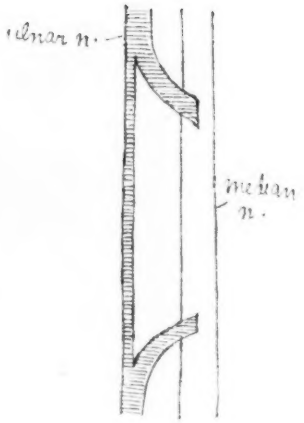


Fig. 11.

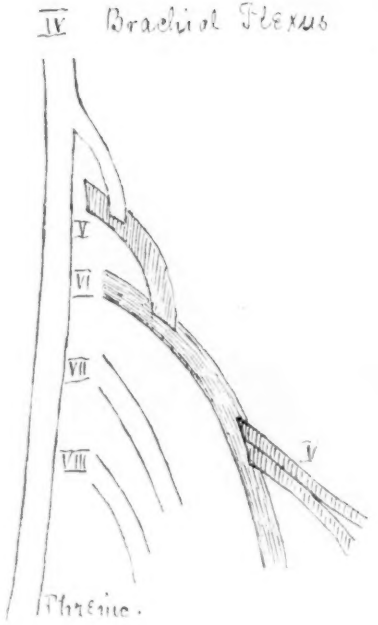


Fig. 12.

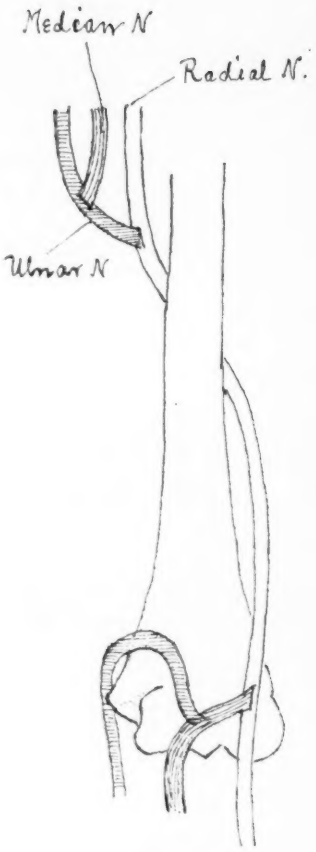
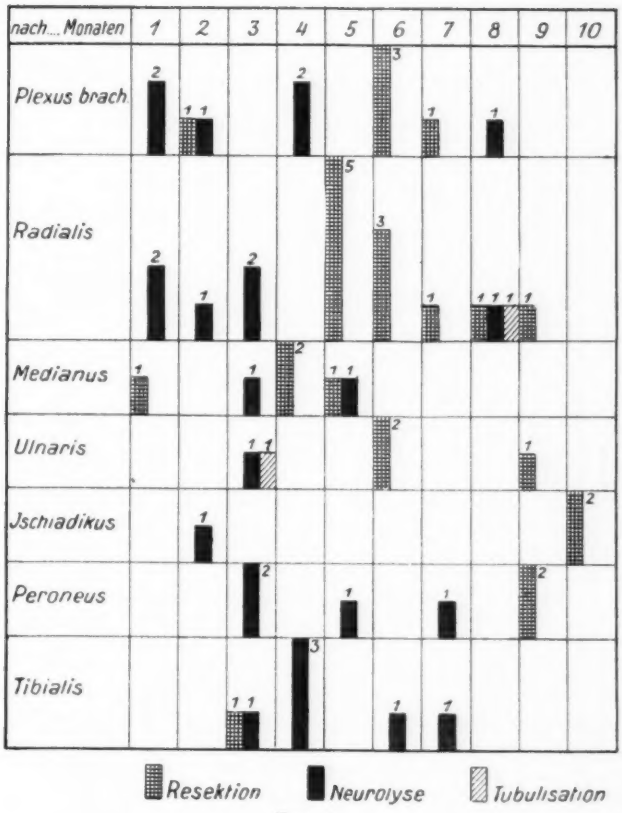


Fig. 13.


nach... Monaten
1
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Plexus brach.
Radialis
Medianus
Ulnaris
Jschiadikus
Peroneus
Tibialis
Resektion
Neurolyse
Tubulisation

FIG. 14.

information of later results, as no medical literature from Germany reaches us at present.

A few words as to the best tissues with which to envelop the site of the nerve suture in order to avoid a new perineural scar. The material used most is calves' arteries prepared with formalin after Foramitti and fat. Of late many surgeons have objected to the use of fascia because, although it heals in in almost all cases, yet it has the tendency to shrink and be changed into scar tissue.

Neuroplasty.—The bridging of large nerve defects has also been tried by nerve plastic. This is done by bringing down a lateral flap from the central stump after the well-known method of tendon-lengthening.

In one of my cases (Case VI) a free graft was taken from the central stump and the defect thus remedied. On the whole neuroplasty after this method has found little favor with surgeons and some consider it useless.

A new idea of nerve-grafting has been proposed by Von Hofmeister. He implants the central stump of the resected nerve into a normal nerve running parallel to it, and the distal stump a little further down into the same nerve, thus using the normal nerve as a bridge. He has used double grafting and multiple graftings in injury of the brachial plexus. A motor nerve, or a sensory nerve, or even a degenerated and paralyzed nerve, as long as it shows no scars, can be used as a bridge. Individual fibres of a nerve which have been injured can also be implanted into those fibres of the same nerve that are still intact.

This method can be used with special advantage on the brachial plexus and the nerves of the arm (Figs. 10 and 13).

Thick nerves like the median and sciatic are well adapted for the grafting of single fibres.

Von Hofmeister reports 24 cases in which this method has been tried with encouraging results, although the time is yet too short to judge the method by definite cures.

Prognosis and Results.—Although German surgeons up to date have been very conservative in judging their results by the different operations in nerve injuries, there are, however, a very large number of complete cures reported by them.

The average time after which a complete cure can be expected fluctuates between six months to one and one-half years.

I have appended the original statistics of Spitzy which were published in March, 1916, and which show the results of his operations, and also give the length of time which elapsed until motility of the paralyzed muscles was re-established (Fig. 14).

CARCINOMA OF THE BREAST*

By John Chadwick Oliver, M.D.

of Cincinnati, Ohio

I have chosen this subject for three reasons. First, because the condition is relatively common. Second, because the diagnosis is comparatively easy, and third, because the treatment, once the diagnosis is established, has been definitely determined.

The stomach, uterus and the breast are the most frequent sites of carcinoma. This disease occurs about twice as frequently in the stomach as in the uterus, and is about twice as frequent in the uterus as it is in the breast.

Statistics.—The statistics taken from the Cincinnati Hospital, extending over the period from 1865 to the present time, show the proportion given above to be fairly accurate.

Statistics taken from the Health Department, which, of course, only records deaths, show about the same condition of affairs.

No doubt each one of us has been impressed by the oft-repeated assertion that cancer is a disease showing a marked tendency to increase in frequency, but we may have accepted this statement without any investigation as to whether the facts bear it out or not.

Having a desire to see what the actual figures are, I have investigated the reports from the census of the United States, statistics for New York City, and also for Cincinnati. My figures from the former sources are necessarily taken from reports appearing in journals, but the Cincinnati statistics have been obtained from a study of the death returns in the Department of Health.

The report in the United States is as follows: "Cancer and other malignant tumors filled 52,420 graves in 1914. Of these, 19,889, or almost 38 per cent., resulted from cancer of the stomach and liver. The death rate from cancer has risen from 63 per 100,000 in 1900 to 79.4 in 1914. This increase has been almost continuous, there having been but two years, 1906 and 1911, which showed a decline as compared with the years immediately preceding. It is possible that at least a part of this indicated increase is due to more accurate diagnosis and greater care on the part of physicians in making reports to registration officials" (*Science*, April 21, 1916, p. 563).

* Read before the Cincinnati Academy of Medicine, October 9, 1916.

Frederick L. Hoffman has an article on "The Cancer Mortality of Greater New York," in the *New York Medical Journal* for December 30, 1913, in which he says: "The probable number of deaths from cancer in the United States during 1913 will be about 75,000. Of this number, approximately 30,000 will be deaths from cancer of the stomach and liver; 12,000 from cancer of the uterus and other female organs of generation; 10,000 from cancer of the peritoneum, intestines, and rectum; 7000 from cancer of the breast, and the remainder, cancer of other organs and parts. In the State of New York, during the year 1912, there were 8234 deaths from cancer, equivalent to a rate of 86 per 100,000 of population, which is above the average for the United States at large. The number of cancer deaths in Greater New York, in 1912, was 4071, and the corresponding cancer death rate of 80.9 per 100,000 of population was the highest on record for the city since the records have been kept. The average cancer death rate of Greater New York for the last five years has been 77 per 100,000 of population, which compares with 94 for London, 109 for Paris, and 107 for Berlin. The corresponding rate for Chicago was 78; for Philadelphia 86, and for Boston 107. In 1912 the cancer death rate of Greater New York was 66 for males, and 96 per 100,000 of population for females. The excess in the mortality of females is almost entirely due to cancer of the uterus and cancer of the breast.

"The cancer death rate of Greater New York has increased during the last twenty years from 59 to 81 per 100,000 of population. The male cancer death rate of Greater New York has increased forty-three per cent., and the female rate during the same period has increased thirty-three per cent. In the old city of New York, or the boroughs of Manhattan and the Bronx, the cancer death rate during the last fifty years has increased from 24 to 86 per 100,000 of population, or at the rate of 253 per cent. during the intervening period. Cancer has increased in Greater New York at all ages, but the increase has been most marked at the ages of fifty-five years and over. The rate at this period of life has increased thirty-one per cent. during the last five years, when compared with the average rate during the previous five years. The rate has increased in all of the boroughs, but not to the same degree, partly on account of the influence of the hospital mortality, since the deaths in institutions are not redistributed according to the residence of the deceased. There has been an increase in the mortality from cancer of all organs and parts, except cancer of the skin, which shows a slight decrease for the last five years compared with the previous five years.

"As far as it is possible to judge, the Jewish and Italian populations are subject to at least average cancer death rates. There are no very trustworthy recent statistics for Greater New York, but the available data for Hungary and the city of Vienna sustain the conclusion that cancer among the Jewish population is of a relatively high degree of frequency. Since a rather large proportion of the Jews in Greater New York are of recent foreign origin, and as such a somewhat select class and mostly of the age period at which cancer is not common, it is readily apparent why, in medical and surgical practice, cancer cases among Jews in Greater New York should not be as frequent as might otherwise be the case. According to the statistics of the board of health for the last two years, the proportionate mortality from cancer among persons of Russian and Italian parentage has been relatively high, so that the foregoing conclusion is sustained by the only available data at the present time."

The statistics for Cincinnati, compiled from 1868 to 1916, show an increase in the number of deaths from cancer, from 36 in 1868 to 396 in 1915. If we figure the death rate in the years in which official censuses were taken, we find that in 1870 there were 42 deaths—population 216,239 persons—about one death to every 5148. In 1880 the population had risen to 255,139 and the deaths from cancer had increased to 105—one death in every 2429 alive at that time. In 1890—population 296,908—deaths from cancer 121—rate one in 2453. 1900, population 325,902, deaths from cancer 121, one in 2693. 1910, population 363,591, deaths from cancer 302, one in 1203. 1915, population (estimated) 406,706, deaths from cancer 396, one in 1027.

In this period of forty-five years the increase in deaths from cancer has risen from one in 5148 to one in 1027. This means that the ratio of deaths from cancer is five times what it was in 1870.

There can be no reasonable doubt in the minds of any one that part of the apparent increase in cancer can be explained by the greater accuracy of diagnosis at the present time, and also by the supposition that some fatal cases of ulcer of the stomach and duodenum are incorrectly ascribed to cancer, but even after eliminating these factors, we must still acknowledge both a relative and absolute increase in the incidence of cancer, and any amount of reasoning cannot explain away the grewsome fact.

Need of Early Diagnosis.—If this awful toll of human life can be checked by early and radical removal of the area involved, we may expect some diminution in mortality in the cases where the uterus or breast is involved, but, because of the difficulty in diagnosis and the

inaccessibility of the stomach, one may be excused for being somewhat pessimistic regarding any considerable reduction in the mortality of cancer of the stomach.

Cancer of the breast should be more amenable to cure than when any of the other organs are affected, because its external position and the accessibility of the part for removal, with an unlimited amount of surrounding tissue, offer us the best opportunity for radical treatment. It would seem, therefore, that early removal of a cancerous breast should be followed by a very good percentage of cures.

If the dictum that cancer is always primarily a local disease, is accepted as a general proposition, subject to some exceptions, it may be stated very positively that the prospect of cure is greatest in the cases in which an early diagnosis is made. The later the diagnosis, the larger the death rate.

The safest definition of "early" is that the growth is small, single and circumscribed with no palpable involvement of the neighboring lymph tracts.

If we are to accept the dictum of the ordinary text-books, these symptoms are not sufficient to make a diagnosis of carcinoma of the breast, but on the other hand, if we wait for the symptoms set forth in text-books, we will have allowed the patient to pass over the period in which she may reasonably expect a cure. I believe, therefore, that except in the case of very young women, a lump in the breast is all that is essential in the making of a diagnosis of carcinoma.

I know that I will be open to the charge of being radical in making this statement as broad as I have, but I feel confident that the lives of a large number of women will be saved by acting on this assumption.

A fibro-adenoma of the breast is for all practical purposes a carcinoma in the making, and should be treated radically. Enucleation if possible. Amputation if necessary.

Time and again I have had the opportunity of observing a recurrent carcinoma in an area from which a fibro-adenoma had been removed sometime previously. In one case, that of a nurse, I removed a small adenoma from her breast, and fifteen years later made a radical operation for carcinoma beginning in the scar left by the previous operation.

In quite a few of my cases we obtained a history of a tumor in the breast which had remained unchanged for a period of years, sometimes as many as twenty, and then became an active carcinoma. It seems wise, therefore, to regard this type of tumor as potentially carcinoma.

Another condition found in the breast of younger women, is that of multiple cysts. Increasing experience leads me to look with very great suspicion upon this condition, because I am convinced that they not infrequently are precursors of carcinoma.

A single cyst is not nearly so apt to become carcinoma: in fact, a single cyst may be looked upon as practically the only innocent growth in the breast.

Tuberculosis of the breast is exceedingly uncommon, and syphilis of this region is a negligible quantity. We may say, therefore, that any lump in a woman's breast is a serious matter, and that unless we are able to convince ourselves that we are dealing with a single cyst, radical measures are indicated.

Need of Careful Examination of Specimens.—For quite a number of years all of the specimens removed have been subjected to careful microscopic examination, and these have led to the knowledge that carcinomatous change in the fibro-adenoma can almost always be detected, provided the examination is made thorough enough.

A point of very great importance from a prognostic standpoint, is the physical characteristics of the growth. A comparatively soft, succulent, rapidly growing tumor is far more malignant and less amenable to treatment than the hard, slowly growing variety.

One may say that as a general propositon the younger the patient the more likely the growth will be rapid and the malignancy great, and the older the patient, the less apt is the growth to be rapid or highly malignant. Carcinoma of the breast in women under thirty-five almost always pursues a rapidly fatal course.

The two following case histories illustrate the reversing of the rules just given above.

CASE I.—Mrs. D., the wife of a physician, was a robust, husky woman, forty-one years of age, who discovered a nodule in the outer, upper quadrant of her right breast. When I first saw her on April 13, 1910, there was a lump about the size of a buckeye in the outer, upper quadrant of her right breast, and the glands in her axilla were palpably enlarged. A radical operation was performed on April 14th, the day after I saw her, and she went home on April 27th. The microscopic report of Dr. F. B. Samson was "very malignant carcinoma."

The patient had a very peculiar mental condition bordering upon melancholia, and this condition was very marked both before and after operation. This patient is alive, well and free from any recurrences to-day (more than six years after the operation).

CASE II.—Miss B., a school teacher, was fifty years of age

when she consulted me about a lump about the size of a hazelnut, in the outer, upper quadrant of the right breast. The axillary glands were not involved. The patient was a thin, wiry woman, with no personal history of any value, except that of pulmonary tuberculosis early in life. She had no history of trauma, and her family record was entirely free from any history of malignant disease. The microscopic report by Dr. C. F. Hegner was "small-celled medullary carcinoma—very malignant."

The patient had local, regional and distant recurrences. She died in about two years of metastases in the lung and elsewhere.

The strange and striking feature of my private cases, is the number of patients that have given a history of perfect health up to the time of the development of a lump in the breast. This statement has been made to me so often that I have been led to the belief that cancer most often affects the robust, and that it is more rapidly fatal in this class of patients.

Pathology.—The more one becomes acquainted with this disease the more uncertain he becomes in his ideas of pathology. He begins to doubt the value of much of our knowledge, and is apt to fall back upon the unsatisfactory statement that clinical results cannot be forecast accurately by microscopic findings. This, however, is merely begging the question, because, as a rule, clinical and pathologic findings do correspond very closely.

It is highly probable that certain types of individuals resist more effectually the inroads of cancer than do others. The nature of this resistance is entirely speculative, but some people seem to be much better culture media (if one may be permitted to use that term) than are others. This difference in susceptibility may be due to a chemical, rather than a physical composition of the individual, and I am inclined to believe that this difference in chemical types is much more important than the picture shown under the microscope. To express the idea in a different way, one may say that some cancers grow rapidly and possess certain histologic features, while others grow more slowly and possess different characters under the microscope, because in the one case the host furnishes a very fertile soil for the growth of cancer while the other possesses a soil not so well adapted to the neoplasm. A further fact tending to prove the existence of a soil favorable to the development of carcinoma, is that quite a number of cases made complete recoveries from the original growth, after operation, only to succumb to carcinoma in another locality, years afterward.

In one of my cases, a carcinoma was removed from one breast,

and thirteen months afterwards, carcinoma developed in the opposite breast. The second breast was then removed and the patient remained free from any trouble for twelve years, but at the expiration of that time, developed a carcinoma of the stomach which proved fatal.

The lapse of time in a case such as this, is too great to permit of the belief that the condition in the stomach was a continuation of the original disease in the breast.

I have had several such cases and they seem to indicate a predisposition of the tissues to the development of carcinoma.

May we not go a step further and say that apparently most persons possess a soil upon which cancer cannot thrive?

It is quite possible, though not as yet capable of demonstration, that the cause of the so-called change from a fibro-adenoma into a carcinoma, is not in the tumor but in a change in the chemistry of the organ in which it is placed. The change in the character of these growths is apt to take place at, or near, the time when a very profound change is taking place in the entire economy of the woman. Is it not more logical to suppose that the tumor finds its pabulum much more acceptable at that time, than it is to assume that there is a subtle change inherent to the growth itself?

To my mind the closest analogy to the development of cancer is that shown by the organs of generation. These organs remain immature and undeveloped for years and then suddenly undergo a transformation that is truly wonderful. Has anybody ever given an explanation for this marvellous change? I know of none that is satisfactory, but I am willing to prophesy that a similar stimulus (chemical?) will be found to account for the development of carcinoma at or near the time of the menopause.

Investigations along chemical lines will probably prove of very much more value than investigations along purely histologic lines. The histology of tumors is probably as well worked out at the present time as it will ever be, but chemical investigation in connection with these growths is but beginning.

ANALYSIS OF 100 CONSECUTIVE CASES

I present for your consideration an analysis of 100 consecutive cases of carcinoma of the breast, upon whom I have operated and of whose records I have been enabled to obtain a complete account. These cases were all private cases.

I have not attempted to draw any lessons from Hospital cases

because of the extreme difficulty of following them sufficiently long to know of the final results.

Before presenting the analysis of the statistics I desire to say that the nature of the operation has shown quite a number of variations according to the peculiarity presented by individual cases. I have not attempted to follow any one technic, but have tried to adapt the incision to the case in hand.

In all of these cases passive movements of the arm have been begun within two or three days after the time of operation. The endeavor has been to have free use of the arm at the end of three weeks. In some of the early cases, immobilization of the arm was resorted to during the time of the healing of the wound. This method was abandoned because of the difficulty of obtaining good use of the arm later on. The only disadvantage that can be ascribed to the early use of the arm, is the possible collection of serum under the scar. This has never proved a matter of any serious import, because the serum can be easily drained off through the line of incision.

Age.—The ages of the patients have varied from 20 to 80. Between the ages of 20 and 30 four cases have been encountered; 10 between 31 and 40; 38 between 41 and 50; 29 between 51 and 60; 14 between 61 and 70; 3 between 71 and 80.

From these figures it can easily be seen that the vast majority of cases have occurred between the ages of 40 and 60.

In 56 of the cases the disease was in the right breast. In 43 the left breast was the seat of carcinoma, and in 2 both breasts were affected. These figures indicate less of a difference between the right and left breast than is found in some statistics.

The outer upper segment was the seat of growth in 32 cases; the disease was central, which also includes the total involvement of the breast, in 23 cases. The upper inner segment was the primary seat in four; the lower middle in five; the upper middle in four; the entire outer segment in nine; the inner lower in two; the lower outer in seven, and the entire inner half in one.

The time between the discovery of the growth and operation was as follows: 20 years, 2; 17 years, 1; 10 years, 4; 8 years, 1; 5 years, 2; 4 years, 1; 3 years, 2; 2½ years, 1; 2 years, 7; 1½ years, 5; 1⅓ years, 1; 1¼ years, 2; 1 year, 15; 10 months, 3; 9 months, 4; 8 months, 3; 6 months, 7; 5 months, 1; 4 months, 5; 3 months, 8; 2 months, 3; 7 weeks, 1; 6 weeks, 4; 5 weeks, 1; 4 weeks, 3; 3 weeks, 1; 2 weeks, 1; 1 week, 2.

The actual number of cases which have survived the three-year

period, is forty-one. The known dead are sixty-five, and in four the result is unobtainable.

Of those living, 1 is alive twenty-one years after operation; 3, fourteen years; 3, fifteen years; 1, thirteen years; 1, twelve years; 1, ten years; 3, eight years; 5, seven years; 3, six years; 3, five years; 3, four and a half years; 3, four years; 5, three and a half years; 1, three and a quarter years; 2, three years.

The successful cases knew of the existence of the disease, previous to the operation: 1, seventeen years; 1, ten years; 1, nine years; 1, eight years; 1, two years; 2, one and a quarter years; 5, one year; 1, nine months; 2, eight months; 4, six months; 2, four months; 4, three months; 2, two months; 1, seven weeks; 1, six weeks; 3, four weeks; 2, one week; 7, unknown duration.

It is interesting to note that twenty-two of the successful cases knew of the existence of the disease for nine months, or less, previous to operation, while twelve of them gave a history extending over from one to twelve years. The difference in the result is not nearly so striking as one would imagine it would be.

Recurrences.—The recurrences after operation exhibit a wide range. In fourteen cases the metastases were internal, this group including both the chest and abdominal recurrences. Seven had secondary deposits in the spine; two in the mediastinum; one in the brain; one in the skull; one in the lower jaw, and one in the sternum and supraclavicular fossa. Nine of the cases had purely local recurrences, and eight of them had local and internal recurrences. The other breast was secondarily involved in one case.

The following shows the time between operation and death in those cases which terminated fatally: 1, twelve years; 1, eleven years; 1, eight years; 1, five years; 4, four years; 1, three and a half years; 3, three years; 1, two and a half years; 2, two years and three months; 6, two years; 1, one year and nine months; 1, one and a half years; 1, one year and five months; 3, one year and three months; 1, one year and two months; 2, one year; 1, eleven months; 1, ten months; 4, nine months; 3, eight months; 1, seven months; 5, six months; 2, five months; 2, four months; 1, three months; 1, four months; 1, one-half day.

An item of interest is that in the first fifty cases operated upon, thirteen recovered and remained well. In the second fifty, twenty-eight cases are alive and well (three or more years after operation). Of the first twenty-five cases, six remained well; of the second twenty-five, seven; of the third twenty-five, twelve; of the fourth

twenty-five, sixteen are alive and well (three or more years after operation).

In but three of these cases have recurrenecs appeared after three years. In one case a mediastinal carcinoma developed four years after operation. In another case a local recurrence was found, and removed, five years after operation, and in one case, carcinoma of the stomach developed eleven years after operation.

These figures indicate that a patient who has passed the three-year limit is pretty safe from subsequent recurrences.

My experience with X-ray treatment of these growths leads to the belief that it is of little, if any, value previous to operation. I am inclined to look with much favor upon the post-operative use of the X-ray in these cases, but my experience in this method of treatment has not extended over a sufficient length of time to justify anything like a positive expression of opinion. I have seen enlarged glands disappear from above the clavicle, but one must always bear in mind the possibility that they may not have been cancerous. This assumption has been borne out by the fact that some glands do not disappear under X-ray therapy.

I shall continue to recommend systematic post-operative X-ray treatment to all of my patients because of its possible benefit.

I have had no experience with the use of radium.

No.	Name	Time between discovery and operation	Breast affected	Segment of breast	Rapidity of growth	Glandular involvement at the time of operation	Time of recurrence	Sites of recurrence	Time between operation and death	Alive	Age	
1	Mrs. B.	15 months	Right	Upper outer	Rapid	Extensive	6 months	Axilla	2 years, 3 months	.....	43	
2	Mrs. S.	1 year	Right	Whole breast	Rapid	Extensive	3 months	Axilla and stomach	6 months	.....	78	
3	Mrs. F.	3 months	Right	Upper outer	Rapid	Slight	3 months	Local and internal	2 years	.....	39	
4	Mrs. D.	1 year	Right	Upper outer	Rapid	Marked	3 months	Liver and pleura	2 years	.....	39	
5	Mrs. A.	?	Left	Upper inner	Rapid	None	½ year	Spine	3 months	.....	55	
6	Mrs. B.	3 years	Right	Upper outer	Moderate	Marked	2 weeks	Brain	1 year	.....	49	
7	Mrs. B.	6 weeks	Right	Upper inner	Rapid	Slight	6 months	Stomach and liver	4 weeks	.....	58	
8	Mrs. C.	20 years, active 12 years	Left	Upper outer	Slow	Moderate	1½ years	Liver	14 months	.....	53	
9	Mrs. K.	6 months	Right	Lower middle	Rapid	Slight	14 months	Axilla (second operation)	21 months	.....	54	
10	Mrs. V.	1 year	Right	Lower	Moderate	Slight	.....	.....	.....	14 years	44	
11	Mrs. D.	2 years	Right	Upper outer	Moderate	Marked	?	?	.....	.....	62	Could not be traced.
12	Miss K.	1 year	Right	Upper outer	Slow	Slight	2 years	Other breast	.....	.....	53	
13	Miss K.	2 years	Left	Upper	Slow	Slight	11 years	Stomach	12 years	.....	65	
14	Mrs. R.	9 months	Right	Outer	Rapid	Extensive	2 years	Abdomen	3 years	.....	49	
15	Mrs. P.	3 months	Left	Upper outer	Rapid	Slight	2 years	Spine	3 years	.....	56	
16	Mrs. P.	6 months	Right	Upper outer	Rapid	Slight	3 years	Skull	4 years	.....	65	
17	Mrs. W.	5 weeks	Right	Lower	Rapid	Moderate	4 years	Mediastinum	5 years	.....	64	
18	Mrs. M.	6 months	Left	Outer	Moderate	Slight	3 years	?	4 years	.....	65	
19	Mrs. G.	18 months	Right	Middle	Slow	Slight	5 years	Local (removed)	.....	15 years	47	
20	Mrs. T.	2½ years	Right	Inner lower	Slow	Extensive	.....	Stomach	6 months	.....	55	
21	Mrs. H.	2 years	Right	Recurrence of axilla	Slow	Extensive	.....	.....	.....	14 years	44	
22	Mrs. W.	4 months	Right	Upper outer	Moderate	Moderate	.....	.....	.....	14 years	48	
23	Miss F.	1 year	Right	Upper outer	Rapid	Extensive	16 months	Local and internal	2 years	.....	48	
24	Mrs. B.	3 months	Right	Recurrent	Rapid	Extensive	?	Lung	9 months	.....	49	
25	Mrs. D.	3 months	Right	Lower outer	Slow	Slight	.....	.....	.....	13 years	65	
26	Miss H.	1 year	Left	Total	Rapid	Extensive	?	?	15 months	.....	58	
27	Mrs. B.	8 months	Right	Upper outer	Rapid	Extensive	2 years	Jaw	3 years	.....	63	
28	Miss S.	2 years	Right	Upper outer	Rapid	Extensive	10 years	Stomach and liver	11 years	.....	58	
29	Mrs. P.	1 year	Left	Upper outer	Rapid	Very extensive	?	?	6 months	.....	65	
30	Mrs. W.	6 months	Left	Upper outer	Rapid	Slight	.....	.....	.....	12 years	47	

31	Mrs. R.	6 months	Right	Lower outer	Rapid	Extensive	.....	.....	.....	3¼ years	68	
32	Mrs. S.	10 months	Right	Entire breast	Rapid	Extensive	3 months	Local	8 months	.....	42	
33	Mrs. M.	10 years	Left	Inner lower	Slow	Extensive	3 months	Local	9 months	.....	48	
34	Mrs. T.	1 year	Right	Entire breast	Rapid	Moderate	3 months	Local and lungs	6 months	.....	50	
35	Mrs. K.	1 year	Right	Upper outer	Rapid	Extensive	?	Lumbar vertebræ	8 months	.....	43	
36	Mrs. I.	4 years	Left	Outer central	Slow	Extensive	?	Lumbar vertebræ	3½ years	.....	56	
37	Miss T.	2 years	Left	Entire breast	Slow	Extensive	1 year	Local right breast, mediastinum	18 months	.....	40	
38	Mrs. T.	10 years	Right	Central	Slow	Extensive	.....	.....	15 months	.....	57	
39	Mrs. L.	6 weeks	Left	Lower outer	Rapid	None	2 months	Sternum and supraclavicular	1 year	.....	51	
40	Mrs. R.	10 years	Right	Recurrent	Slow	Slight	7 years	Both breasts	8 years	.....	38	
41	Mrs. M.	16 months	Right	Total	Rapid	Extensive	6 months	Locally and in lung	17 months	.....	51	
42	Mrs. M.	1 year	Left	Lower outer	Rapid	Extensive	.....	.....	.....	10 years	69	
43	Mrs. C.	3 months	Left	Central	Rapid	None	.....	.....	.....	4 years	65	Died cerebral hemorrhage.
44	Mrs. S.	5 months	Left	Upper outer	Rapid	Slight	.....	.....	.....	.....	71	Result not known.
45	Miss M.	18 months	Right	Upper outer	Rapid	Moderate	.....	.....	Dead	.....	33	
46	Mrs. W.	1 month	Both	Middle lower, outer	Rapid	Extensive	.....	.....	.....	15 years	45	
47	Miss W.	7 weeks	Right	Upper outer	Rapid	Slight	.....	.....	.....	15 years	54	Result not known
48	Mrs. G.	4 months	Left	Inner	Rapid	Extensive	.....	.....	.....	.....		Has new growth in axilla.
49	Mrs. S.	5 years	Right	Total	Slow	Extensive	3 months	Spine	8 months	.....	29	
50	Mrs. W.	18 months	Left	Median	Rapid	Slight	2 months	Liver	7 months	.....	40	
51	Miss D.	6 weeks	Right	Lower outer	Rapid	Slight	.....	.....	.....	8 years	45	
52	Mrs. G.	17 years	Left	Middle	Slow. Six months rapid	Moderate	.....	.....	.....	8 years	47	Recurrence in right axilla after 7 years.
53	Mrs. H.	8 months	Right	Middle	Moderate	Slight	.....	.....	.....	8 years	43	
54	Mrs. S.	5 years	Right	Outer	Moderate	Extensive	3 months	?	9 months	.....	58	
55	Miss B.	4 months	Right	Upper outer	Rapid	None	1¼ years	Locally, lung and general	2½ years	.....	50	
56	Miss J.	2 years	Right	Central	Slow	Slight	Not known	Internal	1 year	.....	54	
57	Miss P.	4 months	Left	Central	Rapid	Extensive	1 year	Right breast and spine	15 months	.....	45	
58	Miss F.	1 year	Right	Upper central	Rapid	Extensive	5 months	Locally	1 year	.....	57	
59	Mrs. C.	8 months	Right	Upper outer	Rapid	Extensive	.....	.....	.....	7 years	69	
60	Mrs. G.	1 year	Left	Upper central	Moderate	Slight	.....	.....	.....	7 years	54	
61	Mrs. D.	1 week	Right	.....	Slow	None	.....	.....	.....	7 years	49	Adenoma removed twenty years
62	Mrs. D.	2 months	Left	.....	Rapid	None	.....	.....	.....	7 years	49	
63	Mrs. J.	?	Right	Total	Rapid	Extensive	.....	.....	½ day	.....	47	
64	Miss N.	2 months	Left	?	Rapid	Slight	.....	.....	.....	.....	45	
65	Mrs. J.	?	Right	.....	.....	Slight	1 year	Liver	2 years	.....	58	

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3	Mrs. F.	3 months	Right	Upper outer	Rapid	Slight	3 months	Local and internal	2 years	.....	39	
4	Mrs. D.	1 year	Right	Upper outer	Rapid	Marked	3 months	Liver and pleura	2 years	.....	39	
5	Mrs. A.	?	Left	Upper inner	Rapid	None	½ year	Spine	3 months	.....	55	
6	Mrs. B.	3 years	Right	Upper outer	Moderate	Marked	2 weeks	Brain	1 year	.....	49	
7	Mrs. B.	6 weeks	Right	Upper inner	Rapid	Slight	6 months	Stomach and liver	4 weeks	.....	58	
8	Mrs. C.	20 years, active 12 years	Left	Upper outer	Slow	Moderate	1½ years	Liver	14 months	.....	53	
9	Mrs. K.	6 months	Right	Lower middle	Rapid	Slight	14 months	Axilla (second operation)	21 months	.....	54	
10	Mrs. V.	1 year	Right	Lower	Moderate	Slight	.....	.....	.....	21 years	44	
11	Mrs. D.	2 years	Right	Upper outer	Moderate	Marked	?	?	.....	14 years	62	
12	Miss K.	1 year	Right	Upper outer	Slow	Slight	2 years	Other breast	.....	.....	.....	Could not be traced.
13	Miss K.	2 years	Left	Upper	Slow	Slight	11 years	Stomach	12 years	.....	53	
14	Mrs. R.	9 months	Right	Outer	Rapid	Extensive	2 years	Abdomen	3 years	.....	65	
15	Mrs. P.	3 months	Left	Upper outer	Rapid	Slight	2 years	Spine	3 years	.....	49	
16	Mrs. P.	6 months	Right	Upper outer	Rapid	Slight	3 years	Skull	4 years	.....	56	
17	Mrs. W.	5 weeks	Right	Lower	Rapid	Moderate	4 years	Mediastinum	5 years	.....	65	
18	Mrs. M.	6 months	Left	Outer	Moderate	Slight	3 years	?	4 years	.....	64	
19	Mrs. G.	18 months	Right	Middle	Slow	Slight	5 years	Local (removed)	.....	15 years	65	
20	Mrs. T.	2½ years	Right	Inner lower	Slow	Extensive	.....	Stomach	6 months	.....	47	
21	Mrs. H.	2 years	Right	Recurrence of axilla	Slow	Extensive	.....	.....	.....	14 years	55	
22	Mrs. W.	4 months	Right	Upper outer	Moderate	Moderate	.....	.....	.....	14 years	44	
23	Miss F.	1 year	Right	Upper outer	Rapid	Extensive	16 months	Local and internal	2 years	.....	48	
24	Mrs. B.	3 months	Right	Recurrent	Rapid	Extensive	?	Lung	9 months	.....	48	
25	Mrs. D.	3 months	Right	Lower outer	Slow	Slight	.....	.....	.....	13 years	49	
26	Miss H.	1 year	Left	Total	Rapid	Extensive	?	?	15 months	.....	65	
27	Mrs. B.	8 months	Right	Upper outer	Rapid	Extensive	2 years	Jaw	3 years	.....	58	
28	Miss S.	2 years	Right	Upper outer	Rapid	Extensive	10 years	Stomach and liver	11 years	.....	63	
29	Mrs. P.	1 year	Left	Upper outer	Rapid	Very extensive	?	?	6 months	.....	58	
30	Mrs. W.	6 months	Left	Upper outer	Rapid	Slight	.....	.....	.....	12 years	65	
											47	

31	Mrs. R.	6 months	Right	Lower outer	Rapid	Extensive	.....	.....	.....	3¼ years	68	
32	Mrs. S.	10 months	Right	Entire breast	Rapid	Extensive	3 months	Local	8 months	.....	42	
33	Mrs. M.	10 years	Left	Inner lower	Slow	Extensive	3 months	Local	9 months	.....	48	
34	Mrs. T.	1 year	Right	Entire breast	Rapid	Moderate	3 months	Local and lungs	6 months	.....	50	
35	Mrs. K.	1 year	Right	Upper outer	Rapid	Extensive	?	Lumbar vertebræ	8 months	.....	43	
36	Mrs. I.	4 years	Left	Outer central	Slow	Extensive	?	Lumbar vertebræ	3½ years	.....	56	
37	Miss T.	2 years	Left	Entire breast	Slow	Extensive	1 year	Local right breast, mediastinum	18 months	.....	40	
38	Mrs. T.	10 years	Right	Central	Slow	Extensive	.....	.....	15 months	.....	57	
39	Mrs. L.	6 weeks	Left	Lower outer	Rapid	None	2 months	Sternum and supraclavicular	1 year	.....	51	
40	Mrs. R.	10 years	Right	Recurrent	Slow	Slight	7 years	Both breasts	8 years	.....	38	
41	Mrs. M.	16 months	Right	Total	Rapid	Extensive	6 months	Locally and in lung	17 months	.....	51	
42	Mrs. M.	1 year	Left	Lower outer	Rapid	Extensive	.....	.....	.....	10 years	69	
43	Mrs. C.	3 months	Left	Central	Rapid	None	.....	.....	.....	4 years	65	Died cerebral hemorrhage.
44	Mrs. S.	5 months	Left	Upper outer	Rapid	Slight	.....	.....	.....	.....	71	Result not known.
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46	Mrs. W.	1 month	Both	Middle lower, outer	Rapid	Extensive	.....	.....	.....	15 years	45	
47	Miss W.	7 weeks	Right	Upper outer	Rapid	Slight	.....	.....	.....	15 years	54	Result not known
48	Mrs. G.	4 months	Left	Inner	Rapid	Extensive	.....	.....	.....	.....		Has new growth in axilla.
49	Mrs. S.	5 years	Right	Total	Slow	Extensive	3 months	Spine	8 months	.....	29	
50	Mrs. W.	18 months	Left	Median	Rapid	Slight	2 months	Liver	7 months	.....	40	
51	Miss D.	6 weeks	Right	Lower outer	Rapid	Slight	.....	.....	.....	8 years	45	
52	Mrs. G.	17 years	Left	Middle	Slow. Six months rapid	Moderate	.....	.....	.....	8 years	47	Recurrence in right axilla after 7 years.
53	Mrs. H.	8 months	Right	Middle	Moderate	Slight	.....	.....	.....	8 years	43	
54	Mrs. S.	5 years	Right	Outer	Moderate	Extensive	3 months	?	9 months	.....	58	
55	Miss B.	4 months	Right	Upper outer	Rapid	None	1½ years	Locally, lung and general	2½ years	.....	50	
56	Miss J.	2 years	Right	Central	Slow	Slight	Not known	Internal	1 year	.....	54	
57	Miss P.	4 months	Left	Central	Rapid	Extensive	1 year	Right breast and spine	15 months	.....	45	
58	Miss F.	1 year	Right	Upper central	Rapid	Extensive	5 months	Locally	1 year	.....	57	
59	Mrs. C.	8 months	Right	Upper outer	Rapid	Extensive	.....	.....	.....	7 years	69	
60	Mrs. G.	1 year	Left	Upper central	Moderate	Slight	.....	.....	.....	7 years	54	
61	Mrs. D.	1 week	Right	.....	Slow	None	.....	.....	.....	7 years	49	Adenoma removed twenty years
62	Mrs. D.	2 months	Left	.....	Rapid	None	.....	.....	.....	7 years	49	
63	Mrs. J.	?	Right	Total	Rapid	Extensive	.....	.....	½ day	.....	47	
64	Miss N.	2 months	Left	?	Rapid	Slight	.....	.....	.....	.....	45	
65	Mrs. J.	?	Right	.....	.....	Slight	1 year	Liver	2 years	.....	58	

No.	Name	Time between discovery and operation	Breast affected	Segment of breast	Rapidity of growth	Glandular involvement at the time of operation	Time of recurrence	Sites of recurrence	Time between operation and death	Alive	Age	
66	Mrs. R.	9 months	Right	Central	Rapid	Extensive	.....	.....	.....	6 years	48	
67	Miss B.	20 years, active 18 months	Right	Outer	Rapid	Extensive	8 months	Local and distant	2¼ years	.....	50	
68	Mrs. A.	3 months	Left	Upper outer	Rapid	Extensive	3 months	.....	9 months	.....	46	
69	Mrs. B.	9 months	Left	?	Rapid	Extensive	.....	Spine	5 months	.....	63	
70	Mrs. A.	6 weeks	Left	Entire	Rapid	Extensive	.....	Lung	6 months	.....	59	
71	Mrs. W.	2 years	Right	Entire	Moderate	Extensive	.....	.....	5 months	.....	31	
72	Mrs. D.	1½ years	Left	Total central	Rapid	Extensive	Very soon	Stomach	4 months	.....	45	
73	Mrs. B.	1 year	Left	Central	Rapid	Extensive	2 years	Local	4 years	.....	52	Pernicious anæmia.
74	Mrs. W.	9 years	Right	Central	Slow	Slight	.....	.....	.....	6 years	51	
75	Mrs. D.	1 week	Right	Upper outer	Rapid	Moderate	.....	.....	.....	6 years	41	
76	Mrs. K.	10 months	Left	Upper outer	Slow	Extensive	11 months	Locally and in neck and thorax	2 years	.....	52	
77	Mrs. C.	?	Left	Upper outer	Slow	Slight	.....	.....	.....	5 years	63	
78	Mrs. J.	?	Right	Upper outer	Slow	None	.....	.....	.....	5 years	50	
79	Mrs. C.	2 weeks	Left	Upper outer	Rapid	Extensive	?	?	2 years	.....	41	Pernicious (?) anæmia.
80	Mrs. H.	?	Right	Upper inner	Slow	Slight	.....	.....	.....	5 years	48	
81	Miss F.	10 years	Right	Upper outer	Slow	Slight	.....	.....	.....	4½ years	45	
82	Mrs. M.	2 months	Right	Upper outer	Rapid	None	.....	.....	.....	4½ years	30	
83	Mrs. S.	1 year	Left	?	Slow	None	.....	.....	.....	4½ years	56	
84	Miss W.	6 months	Right and left	Upper inner	Rapid	None	.....	.....	.....	4 years	26	
85	Miss P.	4 months	Left	Outer lower	Rapid	Moderate	.....	.....	.....	4 years	38	
86	Miss B.	?	Left	Upper outer	Rapid	Moderate	.....	.....	.....	4 years	45	
87	Miss B.	3 months	Right	Outer central	Rapid	None	.....	.....	.....	.....	48	
88	Miss C.	1 month	Left	Lower central	Rapid	Moderate	.....	.....	.....	4 years	47	
89	Mrs. A.	8 years	Right	?	Slow	Slight	.....	.....	.....	3½ years	52	
90	Mrs. R.	3 months	Right	?	Rapid	Moderate	.....	.....	.....	3½ years	37	
91	Miss C.	6 months	Left	Total	Rapid	Extensive	.....	.....	4 months	.....	56	
92	Mrs. S.	3 months	Left	Upper central	Moderate	None	.....	.....	.....	3½ years	57	
93	Mrs. F.	?	Left	Lower	Slow	Slight	2 years	Local	.....	3½ years	77	
94	Mrs. J.	15 months	Left	Outer	Moderate	None	1 year	Nodule in axilla	.....	3 years	50	
95	Mrs. D.	3 years	Left	?	Slow	Extensive	.....	.....	10 months	.....	51	
96	Mrs. Z.	?	Right	Upper outer	Slow	Extensive	.....	.....	11 months	.....	50	
97	Mrs. S.	10 months	Left	Upper outer	Slow	Extensive	?	Spine	4 years	.....	56	
98	Miss R.	?	Left	?	Slow	None	.....	.....	.....	4 years	23	
99	Mrs. G.	?	Right	Central	Slow	None	.....	.....	.....	3½ years	38	
100	Miss P.	1 month	Left	Upper outer	Rapid	Moderate	.....	.....	.....	3 years	36	

AUTOGENOUS FASCIAL RECONSTRUCTION OF THE BILE-DUCT *

By Nathaniel Ginsburg, M.D.

and

John Speese, M.D.

of Philadelphia

The history of the patient, the subject of the title of this contribution, is as follows:

Mrs. E. S., thirty-six years of age, white, No. 28816, was admitted to the Polyclinic Hospital, February 29, 1916. Discharged June 10, 1916. Diagnosis, cholelithiasis.

First Operation (March 6, 1916).—Through an upper right rectus incision, the gall-bladder was found to be atrophic, with a fundus shrunken to about the size of an English walnut, containing a few soft friable calculi. The body of the gall-bladder was elongated, and scarcely greater in diameter than the cystic duct. There were numerous adhesions between this organ and the colon and duodenum, presenting evidence of previous attacks of cholecystitis. The massive fatty omentum was found adherent to the urinary bladder. The appendix had been removed at a previous operation. There was no other evidence of abdominal disease.

Cholecystectomy was performed. The forceps which presumably included only the cystic duct were first inserted between this structure and the liver as suggested by Judd. The common duct, to which the cystic duct was parallel, was caught in the forceps applied to the cystic duct, and both structures were divided in the course of removal of the gall-bladder. The distal end of the common duct was included in the ligature which embraced the cystic artery, while the proximal end remained free. A Mikulicz drain was inserted into the region of the foramen of Winslow, and a split rubber tube was introduced into the kidney pouch of Morrison.

An examination of the gall-bladder and cystic duct immediately following the operation disclosed the accident which had occurred, since the terminal portion of the cystic duct included a small part of the wall of the common bile-duct. Our fears were confirmed twenty-four hours later by the presence of a

* Read before the Philadelphia Academy of Surgery, October 2, 1916.

profuse discharge of bile through the abdominal wound; and the first bowel movement, three days later, was decidedly of the clay-colored type. At no time following this operation did any bile appear in the stools; the drainage through the abdominal wound being excessive. Satisfactory healing of the incision took place, except for the establishment of a biliary fistula. The patient made a good operative recovery.

Second Operation (March 15, 1916).—Nine days following the first operation, the abdomen was reopened through an incision mesial to the previous scar, and careful dissection of the gall-bladder fossa and gastrohepatic omentum was made. The distal end of the common bile-duct was readily found. After considerable difficulty the proximal end of the duct was isolated. Examination showed that division of this structure had taken place half a centimetre below the junction of the right and left hepatic ducts, with some loss in continuity of the duct wall.

Since apposition of the two ends of the bile-duct was impossible, a T-shaped rubber tube was inserted into the proximal and distal ends of the bile-duct, and fixed by catgut sutures. About two inches of the duct needed reconstruction, and this was accomplished by enveloping the rubber tube with a section of posterior rectus sheath fascia, including the peritoneum, taken from the region of the wound. The fascial surface of the transplant was placed in contact with the rubber tube, and both ends were carefully sutured to and around the proximal and distal ends of the bile-duct, and also to the wall of the duodenum. A small rubber drain was placed down to the foramen of Winslow, but not in contact with the newly constructed duct. Bile drainage through the T-tube took place within twenty-four hours, with no leakage around the tube, and the first bowel movement, two days later, showed the presence of bile. For one week following this operation the stools were bile-stained, but thereafter became clay-colored.

Since after this date bile was draining profusely through the tube, and the stools failed to show any trace of bile, it was concluded that the distal end of the tube had broken away, and that further reconstruction of the duct would be necessary.

On the eighth of April, the wound had completely healed around the T-tube, which was draining freely into a bottle. The patient was able to walk, and had lost little weight or strength in spite of her meat-free diet. Until the time of the third operation, on May 23, careful studies of the patient's stools were made, and accurate records of the bile discharge into the bottle through the T-tube were kept. No bile appeared in the stools later than the first week after the second operation, and the amount collected

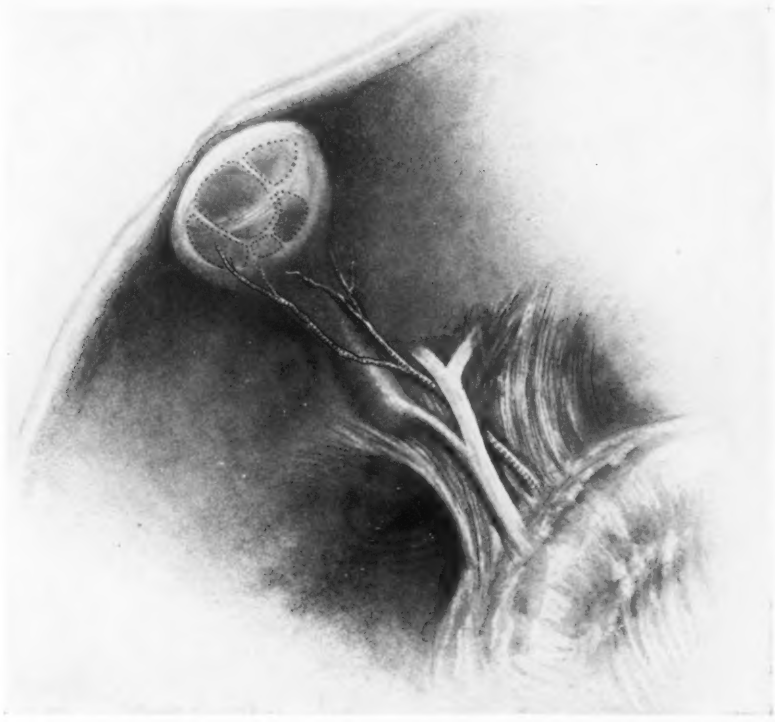

FIG. 1.—Small shrunken gall-bladder. Cystic duct in close proximity and paralleling the common duct. Case reported in this article.

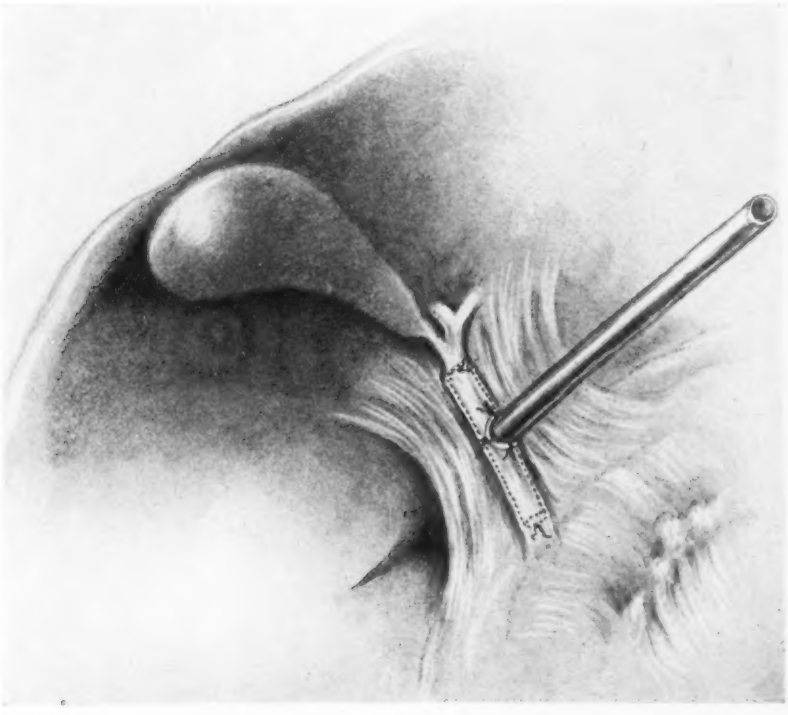

FIG. 2.—Suture of divided common duct around the T-tube of rubber. A simple means of uniting a divided common duct when too much strain is not placed upon the approximation sutures.

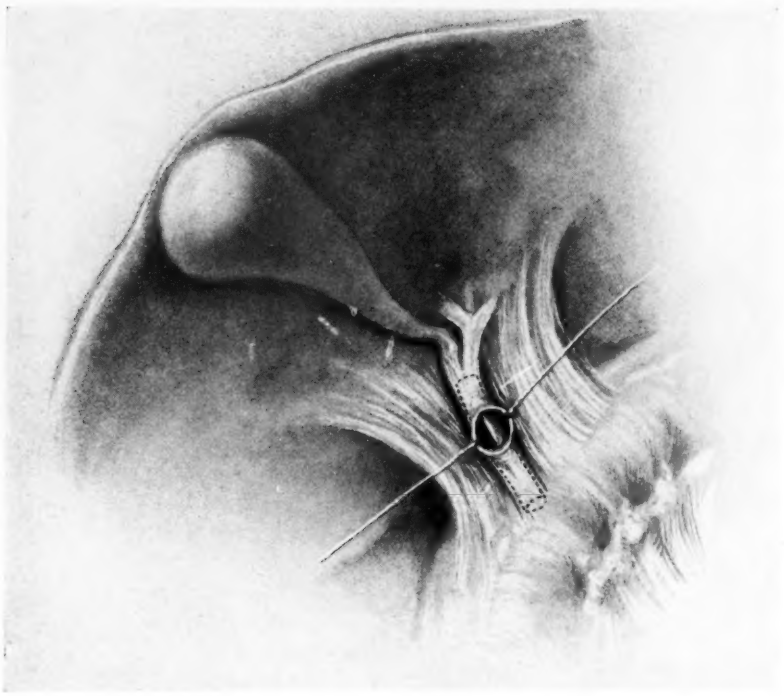

FIG. 3.—Union of divided common duct around the rubber tube, which should pass down into the duodenum. Final closure of the duct is accomplished without necessitating a withdrawal of the T-tube and the subsequent danger of cicatricial stenosis of the bile-duct.

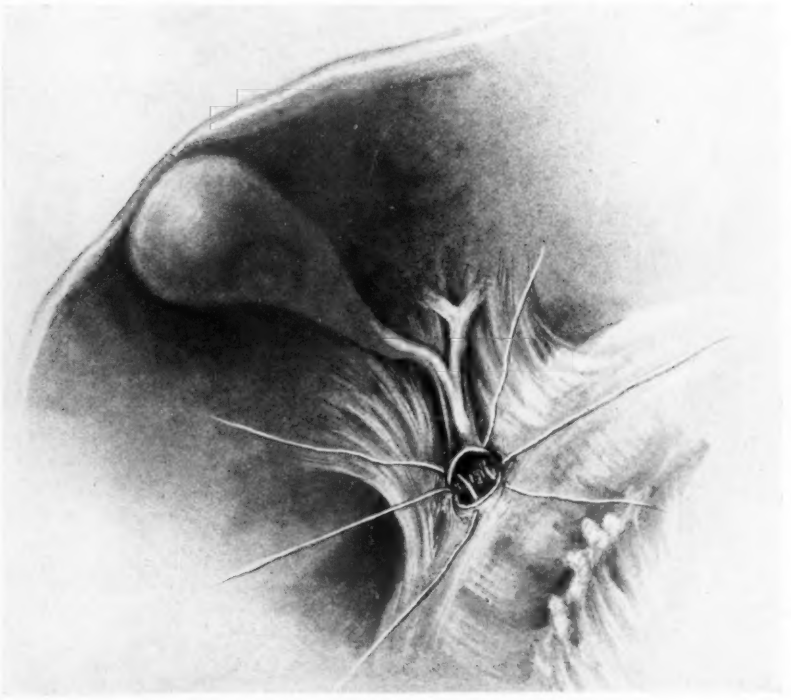

FIG. 4.—Direct suture of the bile-duct into the lumen of the duodenum when sufficient mobilization of the bowel can be accomplished.

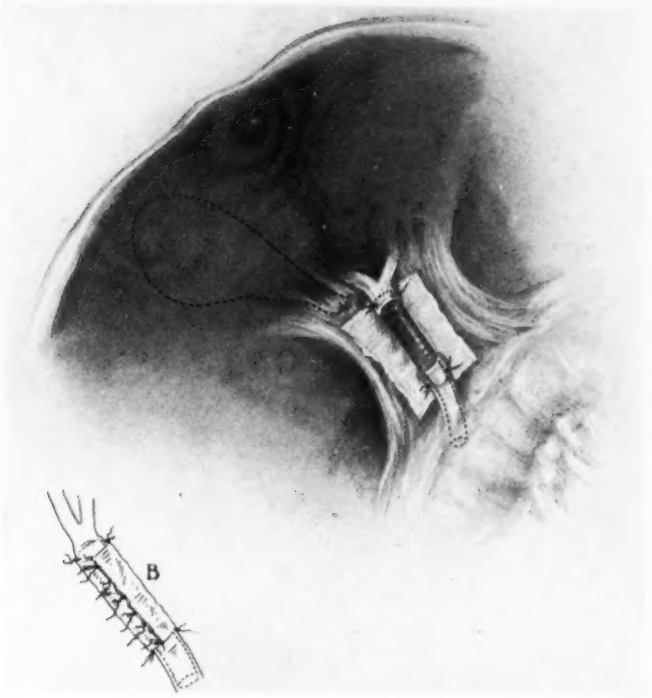

FIG. 5.—Fascial transplant sutured to the proximal and distal ends of the bile-duct into which a rubber tube had been introduced for reconstruction of the bile-duct following cholecystectomy. The graft is sutured securely at both ends; but is not sutured to the rubber tube, which should be passed through the ampulla of Vater.

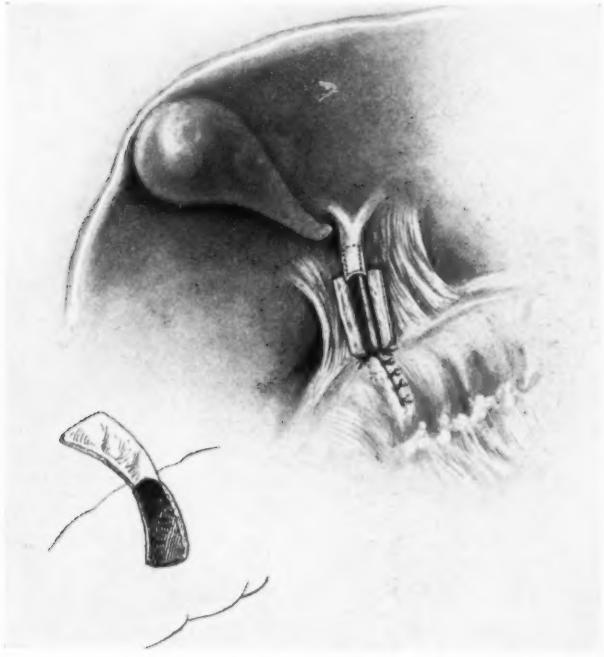

FIG. 6.—Modified Walton operation. Note the duodenal flap with the pedicle above placed behind the rubber tube introduced into the bile-duct and directly into the duodenum. The bowel is sutured up to the point of implantation of the tube.

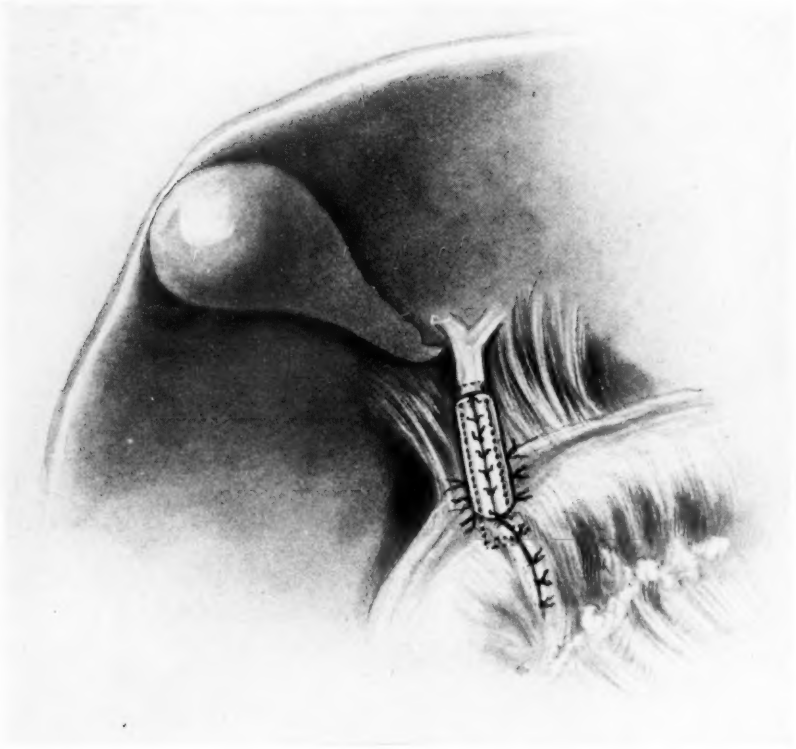

FIG. 7.—Later stage of the modified Walton operation, showing the suture of the duodenal flap to the proximal portion of the common duct, and also around the rubber tube. The suture line is anterior and the reconstruction is made easier by employing this modification.

in the bottle varied from ten to eleven ounces for twenty-four hours.

Third Operation (May 23, 1916).—An incision extending from the ensiform cartilage to the umbilicus opened the abdominal cavity to the median side of the previous right rectus incision. There were dense vascular adhesions between the stomach, duodenum, transverse colon, and great omentum, and the parietal peritoneum. These adhesions were carefully divided in order to facilitate the mobilization of the pyloric segment of the stomach and the upper duodenum.

Employing the T-tube introduced at the previous operation as a guide, the dissection was carried down to the right border of the gastrohepatic omentum. The reconstructed bile-duct was readily isolated and the examination showed that the distal end of the T-tube had broken away at the junction of the fascial transplant with the distal end of the common duct, and was impinging upon the wall of the duodenum. A curved forceps was passed through this portion of the duct into the duodenum, and no evidence of obstruction was found. The T-tube was removed from the common duct, bile flowing freely throughout the operation. A small thick-walled rubber tube, slightly less in diameter than that of the common duct itself, was substituted for the T-tube, and the bile-duct reconstructed around this tube, carefully suturing the transplant to the distal portion of the bile-duct as well as to the wall of the duodenum.

Closure of the duct over the tube was easy of accomplishment, only a few fine catgut sutures being required. Before the rubber tube was passed into the proximal end of the bile-duct, a few syringefuls of salt solution were injected into the rubber tube passed through the ampulla into the duodenum. The gastrohepatic omentum was sutured over the duct to reinforce the line of sutures.

The most difficult feature of the operation was the separation of the adhesions encountered upon entering the abdomen, since the isolation of the distal end of the common duct and the later introduction of the rubber tube were easily accomplished, owing to the presence of the T-tube, which was employed as a guide to the site of the duct. Nature had apparently accepted the fascial transplant and thoroughly reconstructed the common duct, and we believe that if the distal end of the rubber tube, introduced at the second operation, had been passed into the duodenum, bile delivery into the intestine would have persisted. Convalescence was uninterrupted except for some slight superficial infection in the wound.

Fourth Operation (August 17, 1916).—Careful examinations of the stools up to this time failed to reveal the presence of the rubber tube introduced into the common duct at the third operation. Radiographic examination showed adhesions of the stomach and intestine to the anterior abdominal wall. The patient complained of upper abdominal distress following the ingestion of food, and requested another exploration for relief of her symptoms. Excision of the old scars was performed and the upper abdomen was opened. There were extensive adhesions between the upper jejunum, and anterior surface of the stomach, transverse colon and the anterior abdominal wall. These organs were carefully dissected free, and examination of the duodenum in the region of the common duct was made. The rubber tube in the common duct was easily felt passing into the retroduodenal portion of the duct. The duodenum was opened about one inch from the pylorus, and, in spite of carefully directed attempts at palpation, the end of the rubber tube could not be felt in the duodenum for purposes of extraction. The patient was not suffering from common duct crises, and since incision of the reconstructed duct for removal of the tube was not considered feasible, it was deemed advisable to close the duodenal wound, and not attempt the removal of the tube. A small rubber tissue drain was introduced down to the seat of the duodenal incision, and the abdomen closed.

Two days following the operation the patient developed free biliary flow through the drainage tract occupied by the rubber dam. The stools were clay-colored for a period of three or four days, but on August 30, a stool showed copious delivery of bile into the duodenum, and from this time on there was scarcely any drainage through the abdominal wound. It is evident that some injury of the newly-made common duct occurred at this operation through the separation of adhesions, but fortunately was not sufficient in extent to jeopardize the integrity of the recently constructed bile-duct. The patient left the hospital with a well-healed wound, and all bile passing into the duodenum. At the present time, four months since the successful reconstruction of the duct was accomplished, the rubber tube has not been passed, and the patient has not suffered from any symptoms suggestive of biliary colic.

Accidental division or injury of the common bile-duct has occurred in many instances during the course of removal of the gall-bladder. Numerous contributions to surgical literature have recently appeared, dealing with the operative repair of the bile-duct for a deficiency which has resulted from accidental division, or partial excision necessitated

by the presence of a pathologic process obliterating the lumen of the duct.

The cystic duct lies in a fold of the gastrohepatic omentum, which normally passes over, to the pelvis of the gall-bladder, and obscures the duct from view. In order to insure the integrity of the common duct when cholecystectomy is performed, the cystic duct must be isolated for accurate ligation. The importance of this observation has been emphasized by Moynihan, Judd, Brewer, Deaver, and others, who have graphically illustrated operations for removal of the gall-bladder. W. J. Mayo, in a classic contribution upon this subject, has emphasized the important anatomical relationship between the pelvis of the gall-bladder and the cystic duct over which it lies. Grasping and elevating this little dilatation will usually render the cystic duct tense and make its isolation a simple procedure.

There is still some difference of opinion as to whether cholecystectomy is not more safely performed by primary dissection of the gall-bladder from its hepatic fossa, as a preliminary step to the isolation and ligation of the cystic duct. To obviate the danger of accidental division of the common duct when the gall-bladder is removed, the cystic duct should be freely exposed in its enclosed fatty fold of the gastrohepatic omentum and clamped, either including the cystic artery in the forceps, or with separate ligation of each structure. Any procedure which includes the cystic artery and the cystic duct in a single pedicle ligature, without first exposing and clearly defining the duct, will carry with it the hazard of accidentally injuring or actually dividing the common bile-duct.

It seems to us that the most important feature in the technic of cholecystectomy lies in this step of the operation, and does not bear upon whether dissection of the gall-bladder for removal begins above or below. When one can safely isolate the cystic duct, without the danger of injury to the common bile-duct, it is easier to do a subperitoneal dissection of the gall-bladder from below upwards, suturing the fossæ as the dissection proceeds towards the inferior border of the liver.

Partial choledochus excision occasionally becomes necessary for benign strictures of the bile-duct; or when the obstruction to the biliary flow is complete, owing to an impassable mechanical barrier either in the head of the pancreas or at the ampulla of Vater. When the latter condition obtains, cholecystenterostomy is the operation of choice, and should take precedence over any attempt at reconstruction of a new bile-passage.

The immediate repair of the bile-duct, when division is promptly recognized during the course of cholecystectomy, is a simpler procedure than that which follows at a second sitting in the presence of altered anatomical relations, and well organized adhesions between the inferior surface of the liver and the adjacent viscera. Separation of these vascular adhesions is difficult and time-consuming, and the operative procedure carried on in a deep-seated region is handicapped by the absence of the gall-bladder which always serves a valuable purpose for exerting traction upon the liver, and thereby elevating the gastro-hepatic omentum with its enclosed contents.

As a rule, the operative accidental injury or total division of the common duct is not discovered at the time of the primary operation, but its existence is suggested by the early and persisting biliary fistula which follows, associated with total absence of bile in the stools.

The immediate necessity for suture or reconstruction of the bile-duct is not great, since patients with biliary fistula and total absence of bile in the intestine may go on for many months showing little loss of strength or weight. In our own case, the patient developed a biliary fistula lasting many weeks, during which time she discharged all of her hepatic secretion through the wound, and showed no evidence of bile in the intestine. On a meat-free diet she lost but little weight, and other than the inconvenience of her soiled clothing suffered no other ill-effects.

The methods of repair of an injured bile-duct are numerous, and the selection of a particular type of operation is largely dependent upon the features of the individual case and the degree of destruction of the bile-passage which is present. The factors which determine the facility of repair are: Slight injury to the wall of the duct; total division without loss of tissue; and, finally, inability to appose the ends of the bile-duct after division associated with the loss of part of the drainage tract.

The early operations suggested and performed by Riedel, Sprengel, and others, employing lateral anastomosis between the bile-duct and the duodenum either with or without the Murphy button, have chiefly an historical interest and do not afford a simple and certain means of overcoming the difficulty present.

The most satisfactory results have been accomplished during the past ten years, employing methods of repair or reconstruction, of which the following are those attended by the greatest measures of success.

1. *Direct Suture.*—Direct suture of the bile-duct, when recogni-

tion of the division during the course of an operation takes place, can be accomplished by through-and-through chromic catgut sutures similar to the end-to-end anastomosis of a blood-vessel by the method of Carrell. The gastrohepatic omentum should be grafted over the suture line in order to lessen the danger of leakage, and when too much tension does not exist this procedure should suffice. The ease of accomplishment is largely dependent upon the degree of tension to which the sutures are subjected, and the absence of inflammatory changes in the gastrohepatic omentum. Post-operative cicatricial stenosis occurring at the suture line may result after this procedure.

C. H. Mayo has suggested and carried out longitudinal splitting of the distal segment of the bile-duct for a short distance, in order to increase its calibre and render coaptation easier of accomplishment. W. J. Mayo has shown the advisability of employing a T-tube, introduced into the sutured bile-duct for the purpose of establishing drainage until such time as reconstruction of the biliary channel has been accomplished. He emphasizes the importance of directing the distal end of the T-tube through the ampulla into the duodenal lumen, proving this has been accomplished by injecting salt solution through the tube in accordance with the suggestion of McArthur. The T-tube is allowed to remain in place for some weeks, being removed at the discretion of the operator.

This method, when it can be accomplished, is undoubtedly the safest and most satisfactory means of re-establishing the continuity of the common bile-duct following division, or excision of a portion of the duct.

2. *Hepaticoduodenostomy or Choledochoduodenostomy.*—Either of these procedures may be successful when partial excision of the distal portion of the common bile-duct has occurred, or if the patency of this channel is destroyed as the result of disease. Section of the duct above the stricture or obstructive factor with direct implantation into the lumen of the duodenum has been successfully carried out on a number of occasions.

Riedel, in 1881, first performed choledochoduodenostomy, employing a bilateral anastomosis between the bile-duct and the duodenum. This operation proved unsuccessful, owing to leakage of infected bile; but in 1891 Sprengel successfully sutured the bile-duct into the duodenum, having previously performed cholecystectomy.

In 1905 W. J. Mayo sutured the hepatic duct directly into the duodenum, and he has recently reported that the patient is alive and well. This operation has been repeated successfully by others, and is

a valuable method of re-establishing continuity of the bile-duct when sufficient mobilization of the duodenum is possible. However, when the persisting portion of the duct cannot be implanted directly into the duodenum, some other means must be selected to overcome this difficulty. Hepaticojejunostomy has been performed, employing a loop of jejunum in place of the immobile duodenum (Jackson).

Hepaticoduodenostomy has also been employed, a portion of the intestine, usually the duodenum, is sutured directly to the liver after a portion of this organ has been excised, in order to drain bile from the numerous small introhepatic bile-ducts directly into the intestine. The operation is contra-indicated, owing to the dangers of hemorrhage, infection of the liver substance, and the difficulty of successful suture. The mere mention of this procedure is sufficient to condemn it as being irrational and unscientific in its conception.

Reconstruction of the Bile-duct by the Employment of a Rubber Tube with or without the Use of an Autogenous Graft.—This method of repair is indicated in those cases in which division of this structure has taken place with wide separation of the proximal and distal ends, or when a portion of the duct has been excised owing to pathological changes which have occurred in or about the duct.

In 1909 A. G. Sullivan stated that no previous operation had been successfully devised, having for its purpose improvisation of a new duct, when the necessity was created as a result of accidental injury or disease. In his experimental laboratory work employing dogs, he introduced a rubber tube, about the size of a common duct, into the proximal end of this structure and fixed the distal end into a small opening in the duodenum. In placing the rubber tube across the wall of the duodenum, he attempted to create the supra- and retroduodenal relations of the bile-duct. The duodenal wall was sutured over the distal end of the tube, and, by employing gastrohepatic and great omentum, he reinforced his suture line and buried the rubber tube in these structures. His operation was really based upon the method which Hans Kehr, of Halberstadt, Germany, employed when he successfully sutured the gastric wall around a tube which he introduced into the common duct for a deficiency in the wall of this structure.

We believe that successful reconstruction of the bile-duct can be accomplished by means of a fascial transplant surrounding a rubber tube. If simple division of the duct has occurred, the distal end at the second operation is usually found unchanged with the orifice widely open. A rubber tube of proper size is sutured into the distal and proximal ends of the bile-duct. The autogenous fascial graft can

be taken from the posterior rectus sheath and will successfully re-establish the continuity of the biliary channel to a degree approaching the normal. The graft should be firmly and carefully sutured to the distal and proximal portions of the bile-duct and around the rubber tube introduced into the newly reconstructed channel. The distal end of the rubber tube should be passed through the ampulla into the duodenum and should not be fixed by sutures to the fascial graft.

When the distal end of the common duct, as a result of disease or injury, cannot be employed for this purpose, the rubber tube should be introduced into the duodenum through a small opening, and reconstruction accomplished as described. The autogenous graft is more advantageous than the employment of omental tissue, since, after the passage of the rubber tube, there remains a strong fascial tract, which is not subject to the same strictural possibilities as would be the case when strict adherence to the method of Sullivan is employed.

Lewis and Davis successfully employed fascial grafts taken from the abdominal wall in the reconstruction of injured bile-ducts, and reported satisfactory results in their experiments upon dogs. The appendix has been suggested by Molineux as a structure for the reconstruction of the bile-duct; and Giordano, Stropeni, Giacinto and Luigi have employed venous segments to re-establish continuity of the biliary passage where intentional division has been made in dogs. While the appendix is unsuitable for this purpose, laboratory experiments with venous segments have been reported as being successful.

The employment of a rubber tube of sufficient length, extending into the duodenum, surrounded by an autogenous fascial graft, seems to us to be the most satisfactory means of reconstructing either a part or the entire continuity of the bile-duct. The size of the tube and fascial graft are subject to no limitations. Mobilization of the duodenum is unnecessary and the operation is easy of accomplishment. The employment of a T-tube is not desirable, since it makes the reconstruction more difficult and the subsequent withdrawal of the tube will necessarily place considerable strain on the wall of the newly-established duct, creating serious damage, with the danger of subsequent cicatricial stenosis.

W. J. Walton has devised an ingenious operation which consists in indirect implantation. Employing a rubber tube sutured into the proximal end of the bile-duct and passing distally through the wall of the duodenum, he turns down a duodenal flap including the mucous surface of the bowel and sutures this around the distal end of the rubber tube, fixing the free border of the flap by interrupted sutures

to the remaining portion of the bile-duct above. This operation is really hepaticoduodenostomy, with a modification similar to that of Hans Kehr, which consists in employing a flap of tissue lined by mucous membrane from the stomach to line the newly created bile-duct.

We believe that the operation of Walton can be much improved by cutting the duodenal flap with the pedicle above instead of below, and placing it behind the rubber tube employed for reconstruction, so that the suture line will be on the ventral surface of the rubber tube instead of on the posterior aspect. This variation in technic will make the operation easier of accomplishment, and the suture line can be securely reinforced by grafting omental tissue on the newly-built bile-duct. The blood supply of a duodenal flap having its pedicle above will also be more abundant, since the superior duodenal border is richly supplied by branches of the upper pancreaticoduodenal artery.

SPLENECTOMY FOR REPEATED GASTRO-INTESTINAL HEMORRHAGES

By Donald C. Balfour, M.D.

of Rochester, Minnesota

The following case is presented first to call attention to the advisability of considering the splenic factor in those cases of recurring gastro-intestinal hemorrhages in which the positive exclusion of gastric or duodenal ulcer the absence of both splenomegaly and a recognizable hepatic cirrhosis contribute to a difficult diagnostic problem, and, second, because I have been unable to find in the literature any record of splenectomy performed on similar indications.

Case A-97895.—C. W. E. S., a male, aged forty-five, presented himself for examination in the Mayo Clinic, December 30, 1913. With the exception of a tuberculous infection of the cervical glands in early life, his past history, other than that relative to his present condition, was negative.

His immediate complaint was bloody stools. From his clinical record the following facts were abstracted: For twelve or fifteen years he had been subject to epigastric discomfort one or two hours after meals, accompanied by belching of gas with sour eructations. He had noted rather indefinite food relief, but it had never been so decided that he had purposely eaten to relieve the pain. The "indigestion" was not constant, there being periods of complete remission, such periods being of usually a month's duration. About three months previous to his examination, after an unusually severe spell of gastric distress, tarry stools were noticed. Two or three weeks later the stools again became black, and on this occasion dyspnœa on exertion, accelerated pulse, and anæmia resulted. On December 13, two weeks before he came to the Clinic a more profuse hemorrhage occurred.

The physical findings did not aid toward a clinical diagnosis. The essential reports in the special examination of the patient were as follows:

The fluoroscope demonstrated a healed tuberculosis of the apex of the right lung. The first fluoroscopic examination of the stomach was indeterminate. On second examination a possible ulcer on the posterior wall near the lesser curvature was reported. The proctoscopic report was negative. At times the urine showed a trace of albumin but red blood-cells and white blood-corpuscles were always present. The gastric secretions

were of normal acidity. There was a marked secondary anæmia, the blood record being hæmoglobin, 45 per cent.; red cells, 3,350,000; white cells, 5000. The Wassermann test was negative.

A diagnosis of duodenal ulcer was made. The diagnosis was based on the chronicity and the periodicity of the "indigestion" and the bloody stools. Operation was considered urgent on account of the repeated hemorrhages and the marked anæmia.

On January 13, 1914, the patient was explored. The operative findings were most unusual. The pyloric end of the stomach was markedly dilated and enormous varicose veins were present in this portion of the stomach and along the lesser curvature. There was a distinct œdema of the pancreas which extended into the neighboring lymphatic glands. Ulcer was not demonstrated. The gall-bladder, however, contained one stone impacted in the pelvis. The thickened gall-bladder, the large glands, and the condition of the pancreas seemed sufficient indication for cholecystectomy. Several of the large veins on each side of the pylorus were also ligated.

The patient recovered satisfactorily from the operation and returned home. Soon after his arrival there, however, he had two copious hemorrhages from the bowel and returned to the Clinic March 21, 1914. The hæmoglobin at this time was 40 per cent. and it was thought that either a small, actively bleeding ulcer had been overlooked, or that the varicose gastric veins in some way were responsible for the bleeding. These veins were a feature of unusual interest, for such extreme varicosity in this situation is rare, and it is important to note that fatal hæmatemesis has occurred in which no pathologic condition other than this could be demonstrated.

At the second operation, March 26, 1914, the pylorus was found bound down by adhesions, which were not separated. The varicose veins had become somewhat reduced in size since the former operation, and the pancreatitis was less evident. A posterior gastro-enterostomy was done on the assumption that the bleeding was due to erosions of the gastric mucous membrane.

Comparatively soon after this operation the patient began to show progressive improvement in the blood picture, and in November, 1914, his hæmoglobin and the red cells reached 84 per cent. and 4,680,000, respectively. At this time he consulted us in reference to an enlarged epididymis which was apparently tuberculous in character. December 7, a left epididymectomy with resection of the vas for tuberculous epididymis was done. His general condition was now so satisfactory that it was thought advisable to investigate the genito-urinary tract on account of the constant presence of blood-cells in the urine, the small

amount of pus, and the tuberculous epididymis. Cystoscopic examination showed the left kidney to be tuberculous and the right functionating well. On December 20, 1914, a left nephrectomy was done; the cortex of the kidney contained tuberculous abscesses.

After the nephrectomy his condition remained good until the following October (1915), when intestinal hemorrhages again occurred. There were no other symptoms except those directly incident to the bleeding. While under our observation he continued to pass black stools. On October 8, 1915, the hæmoglobin was 43 per cent. Various " remedies "—tannin, coagulin, emetin, irrigations of the stomach with hot water (130 degrees) through a tube—were tried with no relief, and on October 9 the patient was again explored.

Extensive adhesions were met with through the upper abdomen. A thickening on the anterior aspect of the gastric side of the gastrojejunal opening was found which was looked upon at the time as an ulcer. This was excised with the Paquelin cautery and closed by suture. Very free bleeding occurred during the closure of the opening. It was hoped that this area had been responsible for the recurrence of the bleeding. The patient did well for a few days and then began to vomit bile. This was not corrected by repeated gastric lavage and the condition finally became so critical that an entero-anastomosis between the two loops of intestine was necessary. This was combined with a jejunostomy with a catheter to be utilized for auxiliary feeding. The patient recovered from this procedure and went home in fair condition.

He returned to the Clinic three months later (December, 1915), reporting that he had passed a quantity of dark blood on two occasions during the previous week, and for the first time had vomited a small quantity of blood the day before he returned. Examination of the blood showed the hæmoglobin to be 35 per cent. He was kept under observation. The hemorrhages continued in spite of measures used to control them, and by January, 1916, the hæmoglobin had dropped to 28 per cent. with about 3,000,000 red cells, and every stool examination showed blood.

The persistency of the hemorrhages and the fact that by reason of the results of splenectomy, the spleen has been proved responsible for certain types of anæmia associated with hemorrhages of the mucous membrane, led to the consideration of splenectomy, although no enlargement of the spleen had been noted previously. On February 1, therefore, the patient was again explored through a left rectus incision and the spleen, which had been questionably palpable at the costal margin previous to operation, was found to

be twice normal size, its weight being 285 Gm. Although the liver was not distinctly cirrhotic, an "apparently moderate cirrhosis" was noted. Splenectomy was not particularly difficult, but as the patient was in very poor condition as a result of the repeated hemorrhages (he vomited blood on the operating table) it was of grave risk.

Recovery following removal of the spleen was necessarily slow; nevertheless it was steady and at the present time, seven months after the operation, the patient is in better health than he has ever been. He weighs 200 pounds; has had no sign of bleeding since the spleen was removed, and it is confidently expected that there will be no recurrence of the hemorrhages.

The difficulty in the correct interpretation of gastro-intestinal hemorrhages is recognized by many careful observers. Preble estimates that in two-thirds of such cases a diagnosis of the cause of the hemorrhages cannot be made. In this instance, the absence of an alcoholic history with the long-standing indigestion supported the erroneous diagnosis of duodenal ulcer. Aside from lesions of the stomach or intestinal tract, the most frequent cause of gastro-intestinal hemorrhages is splenic anæmia or primary hepatic cirrhosis. Unfortunately the clinical features and the operative findings cannot be looked upon as sufficient to make a positive diagnosis of either of these conditions. It is true, however, that the prominent symptoms in this case show a striking similarity to those which have been attributed by writers as characteristic of unrecognized or "latent cirrhosis." Preble and others have reported fatal gastro-intestinal hemorrhages associated with unsuspected cirrhosis and Armstrong describes a case in which the necropsy disclosed no pathologic changes.

The prompt arrest of the bleeding following removal of the spleen at least suggests that the spleen, either directly by some toxic influence or through the medium of the liver, was responsible for the hemorrhages. The patient (who, by the way, contributed much to the satisfactory result by most intelligent coöperation) had observed that in the later months of his illness, as soon as the hæmoglobin had reached about 45 per cent., intestinal hemorrhages invariably occurred, showing that even during periods of freedom from bleeding, the tendency to bleed was always present.

Aside from the interest centered in the diagnostic problem, observations of distinct importance may be made. The inadvisability and the futility of gastro-enterostomy, unless an ulcer can be seen or palpated, has long been noted by various observers, but some cases have been reported in which "erosions" have been found at operation

and in which good results have followed gastro-enterostomy. It is quite possible that in some cases of gastro-intestinal hemorrhage demonstrable erosions of the mucous membrane may be present. Armstrong reports a satisfactory result following the searing of such a surface in the gastric mucosa, with a Paquelin cautery. These erosions are in all probability "toxic" in character.

On the other hand, the hemorrhages occurring in the cirrhosis, as far as I can determine, have never been associated with actual erosions, but have depended rather on changes in the blood-vessels and a low fibrinogen content of the blood (Whipple). This instability of the blood-vessels is shown in the tendency to petechial hemorrhages and the oozing from lips, gums, lungs and even ears in cirrhosis. In this case, although no definite destruction of mucous membrane was demonstrated, C. H. Mayo called attention to the highly congested mucous membrane which bled at the slightest touch.. Taylor reports the case of a patient dying from a hemorrhage ten weeks following gastro-enterostomy for supposed ulcer, the necropsy revealing a marked hepatic cirrhosis.

There is an excellent illustration of the efficiency of an entero-anastomosis as a relief for bile vomiting due to an imperfectly functionating gastro-enterostomy. Most important, however, is the lesson that in every case of anæmia, and particularly when the cause of the anæmia is not obvious, the spleen should be considered, and should be explored when an opportunity is offered. Similarly, in cases in which gastro-intestinal hemorrhages are the predominating symptoms and no ulcer can be demonstrated, the liver also should be carefully inspected and a section excised for immediate microscopic examination.

Although such gastro-intestinal hemorrhages have been usually attributed to an hepatic cirrhosis, recent developments in surgery of the spleen provide a formidable array of facts to throw considerable doubt on the assumption that the liver is the only factor in these cases. Chauffard was one of the first to point out the possibility in some cases that cirrhosis is secondary to processes originating, or at any rate most marked, in the spleen. The many evidences, both clinical and experimental, of the intimate relationship of spleen and liver; the excellent results following splenectomy in splenic anæmia (a disease which is characterized by a tendency to develop cirrhotic changes in the liver, and by gastro-intestinal hemorrhages); the fact that gastro-intestinal hemorrhage has been reported as being associated with a "latent" cirrhosis but in which the most marked finding was an hypertrophied spleen; and last, the results of splenectomy in various blood diseases

are facts which give much prominence to the splenic factor in these obscure blood dyscrasies.

It would appear, therefore, that the result of the splenectomy herein reported opens up a wide and inviting field for investigation.

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ENTEROSTOMY FOR ILEUS*

By Charles N. Dowd, M.D.
of New York
surgeon to the roosevelt hospital

In the last two years, at least seventeen articles dealing with intestinal obstruction, or ileus, have appeared, or have been extensively reviewed, in the larger American and English surgical and medical journals. Ten of these have been based upon clinical study, some of them analyzing long series of cases, and giving guides for diagnosis and treatment. Seven of them have been based upon laboratory study, with special endeavor to determine the nature and peculiarities of the toxic substances which are developed when the intestines are occluded. This large amount of thought and study indicates the present importance of the subject.

Type of Cases.—A very large part of the clinical study has dealt with the sequelæ and complications of appendicitis, but inflammations of the pelvic organs, other forms of intra-abdominal inflammation, and strangulated hernias have also contributed their share of obstructions.

One may see and operate upon scores of cases of appendicitis and other abdominal lesions, and not find among them a single serious intestinal obstruction, and all surgeons aim to use technic which guards against the development of such complication. But, on the other hand, in spite of skill and care, one may find patients whose lives will be sacrificed unless obstruction is relieved by operation.

The post-operative problems are the most puzzling. Peritonitis is present at the time of the operation. During the few days which follow, it has usually been so controlled that no harm results, but occasionally abdominal distention and constipation persist, pain and vomiting appear, and the patient's condition becomes serious.

Pathology.—Under these conditions the surgeon must decide whether the prime factor is peritonitis or mechanical obstruction. There are really three elements to consider: (1) Mechanical ileus; (2) paralytic ileus; (3) peritonitis.

In the articles above referred to, the belief in mechanical ileus is much more pronounced than it would have been in a similar series of articles written ten or fifteen years ago. During this period, the methods of preventing peritonitis have improved, the number of ab-

* Read before the New York Surgical Society, October 11, 1916.

dominal operations has increased; secondary operations, before terminal peritonitis is established, have become more common; and animal experiments have shown the marvellous power of the toxins which develop within the occluded intestine, entirely independent of peritonitis; hence the mechanical element in these cases has become better understood.

McLean voices the opinion of many surgeons and laboratory workers when he says, " It is our opinion that many patients suffering from peritonitis and ileus die, not of the peritonitis but of the ileus."

In considering this subject, we must remember that Sweet, Draper, and Whipple and their coworkers have found that toxic substances develop in the occluded part of the duodenum of dogs so virulent that $^1/_{10}$ Gm. will kill a fifteen pound dog within a few hours.

Paralytic ileus is not well understood, and we have no pre-operative method of distinguishing it from mechanical ileus. It frequently accompanies peritonitis, but sometimes, as in cases reported by J. E. Adams, seems to be caused by trauma. When the autonomic nervous system is better understood, a better knowledge of paralytic ileus may be obtained.

The distinction between mechanical ileus and advanced diffuse peritonitis is very important. The former can be relieved by a simple operation, while operation for the latter too often brings discredit upon surgery and disappointment to all concerned. This distinction is the more difficult because both elements are usually present. Intestine which is obstructed by adhesions, or which is held quiescent by paralysis, is prone to infection, while, on the other hand, infected intestine is likely to show adhesions and obstructive angulations.

Symptoms.—If a patient goes for several days after operation without symptoms of peritonitis, and then, in spite of medication, has obstipation, distention, vomiting, and perhaps visible peristalsis, and if the general depression and increase in temperature and pulse rate are not as marked as would be expected from diffuse peritonitis, we may believe that mechanical ileus is present, and operation should be done. If similar conditions arise, even without the preceding period of quiescence, the question of operation is still to be considered. Well-timed enterostomy in suitably selected cases relieves the intestine of its toxic substances and prevents the development of ungoverned peritonitis.

It is assumed that careful and persistent efforts at relief by non-operative measures are to be used before operation is resorted to. Dr. Gibson presented this phase of the subject to the Society, last

year, and emphasized the value of pituitrin in this treatment. It is to be remembered that most patients will recover without operation if suitable enemata and medication are used. This, however, does not detract from the necessity of operation for the few patients who do need it.

Types of Operation.—In the literature above referred to, the following methods of operation are given: (1) Separation, or division, of adhesions or obstructive bands; (2) enterostomy; (3) anastomosis around the obstructed part of intestine, without resection; (4) resection, with immediate anastomosis (one-stage operation); (5) resection, with immediate artificial anus, and, later, anastomosis (two-stage operation); (6) various combinations of these procedures.

Of these procedures, the division of obstructive bands, or adhesions, is of course to be preferred, and is to be done whenever such bands or adhesions are the apparent cause of the obstruction. If there is distended gut above such obstruction and collapsed gut below it, the indication is of course manifest.

The occasions for the more extensive operations do not often come in the acute cases which we are considering. When they do come, gangrenous intestine or cancer usually gives the indication, and the resection is to be carried out on well-recognized surgical principles.

Our main attention may therefore be given to those cases for whom enterostomy is indicated.

Enterostomy and Its Sequelæ.—The operation of enterostomy is a very old one, and has been in use, at least, one hundred and twenty-nine years, since Renault's time. It is resorted to now much more frequently than it used to be. The details of the procedure differ with the case. Sometimes, without anæsthesia, a little opening is made in a loop of intestine which presents in the drainage wound; sometimes, under local anæsthesia, a small abdominal incision is made, a catheter, or small tube, is tied or stitched into an opening in the intestine, and a few Lembert stitches secure the intestines to the abdominal wall; sometimes, under general anæsthesia, a search is made for a definite obstruction, and failing to find this, an enterostomy opening is made with careful provision for the subsequent closing of the wound.[1] Sometimes, at the termination of a primary operation in unfavorable cases, an enterostomy is done as a safeguard. In all instances, the stoma should be as small as will be efficient.

[1] As brought out by Dr. Lilienthal in the discussion of the paper "A Catheter Inserted According to Witzel's Gastrostomy Method Has Many Advantages."

Nothing in surgery is more dramatic than the improvement which comes from fortunate enterostomy. A patient who is almost moribund before the procedure is, a few hours later, comfortable, bright, and hungry. The change seems little short of miraculous. But, although the immediate improvement is so marked, the patient is not yet well. The original cause of obstruction is still to be dealt with, and the enterostomy opening is yet to be closed. The obstruction is frequently temporary. If there are many angulations in a moderately inflamed intestine, the total obstruction may be sufficient to produce stasis. Such obstruction, however, ceases if the distention can be relieved, and if the inflammation subsides.

A temporary disturbance of the sympathetic nervous system may, also, be a factor. The term "paralytic ileus," little understood but frequently used, indicates a belief in such disturbance. This, too, is believed to be temporary. Since the inflammation, a portion, at least, of the inflammatory exudate and the paralysis all tend to subside when the distention is lessened, it is evident that enterostomy will permanently relieve the obstruction in many instances. In other instances, however, the obstruction must be relieved by a second operation. The division of adhesive bands, or the resection of portions of intestine, are to be done according to the indications found at that operation.

The Care and Subsequent Closure of the Enterostomy Opening.— The subsequent behavior of the wound depends upon its structure and upon its site. If it is so constructed that there is sufficient serous or muscular tissue between the intestinal mucous membrane and the skin, and if there is no spur between the afferent and efferent loops, spontaneous closure is likely to result. If the opening is below the ileocæcal valve, the fecal discharge causes very little skin irritation; if it is much above it, there is apt to be more or less digestion of the skin by intestinal fluids, and a most annoying condition results. The skin may be raw for a wide area about the stoma, causing great discomfort and pain. In addition to this, there may be serious inanition. This condition is not common, but it occasionally occurs and is most pitiable. Handly has been so impressed with it as to describe the procedure as barbarous, and to advocate the more dangerous operation of ileocolostomy instead. One purpose of this paper is to describe a method of preventing this condition.

The suggestion came from seeing an obturator which Dr. S. W. Pallister, of Brooklyn, had used. In working over the subject, it was found that if a flat piece of wood, or similar hard substance, was held firmly against the intestinal opening from within, fecal leakage

FIG. 1.—Easily constructed obturator for preventing leakage from enterostomy opening made from button-mould, spool shank and button.

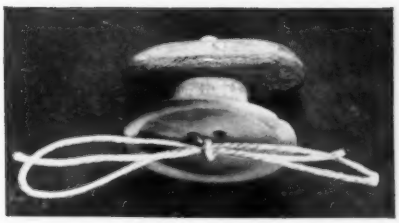


FIG. 2.—Same obturator closed.

FIG. 3.

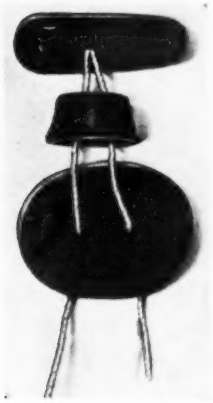
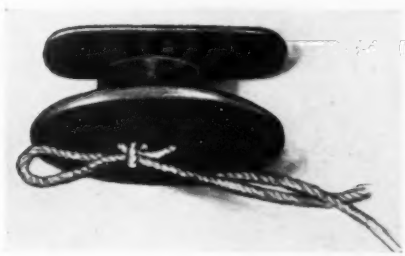


FIG. 4.



FIGS. 3 and 4.—Better finished obturator constructed by instrument maker.

would almost cease. After working over various models, I found that a button-mould, a button, and the shank of an ordinary sewing-thread spool make a very efficient and easily constructed apparatus. It may be used until the more finished model is obtained from the instrument maker or until the stoma is closed by operation. Figs. 1-4 explain the apparatus.

The inner disc, oblong in shape, is pushed through the stoma lengthwise. It should be large enough to occlude the stoma when pulled flatly against it. The shank should fit the stoma, and should be adjusted to the thickness of the abdominal wall. A knot larger than the hole in the inner disc is tied in the middle of a piece of string, the free ends are then passed through the inner disc, the shank, and the two holes in the outer disc, or button. With the string slackened, the inner disc is inserted through the stoma. The string is then tightened and tied firmly, thus fixing the appliance into the shape of a collar button, with one flange inside the intestine and the other flange outside the skin. The intestinal leakage is thus stopped, the skin irritation disappears, and the patient's nutrition improves.

In one instance, in the writer's experience, the result of this procedure was apparently life-saving. A young man whose emaciation was extreme, and whose abdominal skin was raw over a very large area, promptly became comfortable and well-nourished, and a successful closure of the stoma by suture was soon possible.

With this resource, one may more often do enterostomy for the severe forms of ileus, feeling confident that those patients who make immediate recovery will not have distressing convalescence.

The closure of the enterostomy opening occurs spontaneously in many cases. Most of the remaining cases may be easily closed by operation.

Beer and Coffey have each described excellent methods of closing the stomas by simple operations which are almost devoid of danger. The essential steps are three: (1) Closure of the intestinal opening; (2) support of the suture line by firm or fatty tissue; (3) provision for drainage at a distance from the suture line. They give excellent plates to illustrate their methods.

My own operations have been based on these principles: The intestine has been loosened from its adhesions to the abdominal wall, but a very wide exposure of the peritoneum has been avoided. Through-and-through stitches have then inverted the edges of the intestinal stoma; Lembert stitches have reënforced the suture line, and almost

complete closure of the abdominal wall, in layers, has followed. This closure has not been absolutely complete, as provision has always been made for drainage at a little distance from the intestinal sutures.

Intestinal resection is a severe operation, and is to be avoided when possible. Coffey quotes Makins, Bryant, and Tillman as giving a mortality rate for this procedure of 38 4/10% to 27%. To-day's statistics would probably show a lower rate than this, but, at best, the operation is much more severe than the simpler one described above, and is to be avoided whenever possible.

CASE I (Roosevelt Hospital).—A-7182. I. S., aged seventeen. Appendectomy January 16, 1916, for gangrenous appendicitis. Much foul-smelling pus present. He did reasonably well, but, January 31, had developed symptoms of intestinal obstruction which were very threatening. His temperature was 102°, pulse 132, respiration 28, white blood-cells 23,800, polymorphonuclears, 78 per cent., obstipation in spite of enemata, pituitrin, and other medication. He had marked abdominal distention, vomiting, and visible peristalsis. Incision was made through the right rectus in the hope of relieving the obstruction. The small intestines were distended and red. There was considerable free fluid in the abdominal cavity. The large intestine was not distended. The maximum of inflammation was in the pelvis. The adhesions were broken up, gas was pushed from one loop to another, cigarette drains were put into the pelvis, and the abdomen was closed without enterostomy in the hope that the obstruction had been relieved. The following day, however, no relief had come, and the patient was in a desperate condition. Temperature 103.6°, pulse 144. A small opening was made in the lower part of incision, the protruding loop of intestine was opened, and a Paul tube inserted. Considerable fecal matter and gas passed through this. The next morning his distressing symptoms had disappeared, his pulse was much better, his temperature was 98.8° and he was asking for food. He progressed favorably for about ten days, but by that time showed inanition from the leakage of intestinal contents. The abdominal wall was much digested, raw, and tender. After consultation with Dr. Julius Weinstein, various kinds of diet were used and various methods of dressing, but the patient's condition was still critical, and his emaciation extreme. A wooden button was then inserted into the enterostomy opening and made fast. The leakage almost ceased, the raw condition of the abdomen quickly improved, and by the first of April we were able to close the wound by

means of inner stitches through all the coats of intestine, reënforced by Lembert stitches, and further protected by abdominal wall which were sewed in layers in front of them, leaving a little loose spot for the emergence of the discharge, if any should occur. On May 15, when the patient left the hospital in good condition, this had closed to a pin-sized opening, and it completely closed soon afterward.

CASE II (Roosevelt Hospital).—A-7128, S. G., aged 14, April 5, 1916. Two years previously, in another city, ileus occurred three weeks after an operation for appendicitis with abscess. Ileostomy done. He had worn obturators diminishing in size from time to time, ever since. Stoma closed by operation April 5. Intestine freed from its attachment to abdominal wall. Intestinal edges inverted by through-and-through stitches. Suture lines reënforced by Lembert stitches. Abdominal wall almost closed over them. No intestinal leakage. Left hospital twenty-five days later with wound almost healed. Complete healing two weeks later.

CASE III (Roosevelt Hospital).—A-7227. Mrs. N. D., February 10, 1916. Came to hospital with symptoms of intestinal obstruction. Constipation complete. Vomiting, distention, visible peristalsis. The large intestine was distended up to the splenic flexure, and flat beyond. No definite band or growth could be found in that place, but after manipulation the gas passed through into the descending colon, and the wound was closed. Patient did well for three weeks, then symptoms recurred. An enterostomy was done at the caput coli. Entire relief of symptoms. Button worn for considerable time to control intestinal discharge. Movements by rectum followed this. She finally left the hospital without further operation, with the stoma still open, expecting to have this closed at a later time.

CASE IV (Roosevelt Hospital).—A-7987. W. S., aged seventy. September 20, 1916. Extreme vomiting, distention of colon and small intestine. Patient in condition of profound depression. Symptoms had been recurring for several months. X-ray had indicated obstruction in hepatic flexure of an enormously distended colon. Enterostomy at the caput coli done as emergency life-saving procedure. Rapid gain in strength. Obturator introduced one week later nearly controlled the fecal leakage. Worn a few days, was then removed to allow the muscular part of the incision to heal more firmly before further surgical procedure. Patient now wearing obturator, and having stools per ano.

CASE V (Roosevelt Hospital).—A-5698. W. W., aged twenty-eight. December 12, 1915. Patient came to the hospital

with a prolapse of the colon through a colostomy wound in the transverse colon, which had been opened through an incision in the left rectus. His rectum had been excised in another city. The colostomy wound in the left inguinal region had later become obstructed, and, in an emergency, a colostomy had been done in the transverse colon to relieve the obstruction. The portion of the transverse colon above this opening had become so prolapsed that about six inches of the intestine hung down through the opening. The first operation, December 15, 1915, reëstablished the left inguinal colostomy; the second operation, January 3, 1916, united the walls of the stoma in the transverse colon by through-and-through stitches of catgut, reënforced by Lembert stitches and further strengthened by partial closure of the abdominal wall. Healing was not satisfactory after this operation, and, on January 21, a clamp was put on the spur of intestine. On February 14, the edges of intestine were brought together as at the time of the first operation, and healing was easily obtained. Patient left the hospital on March 9, in excellent condition and with his wound healed.

CASE VI (Roosevelt Hospital).—A-6340. Mrs. B. H., aged thirty-nine. Discharged August 15, 1915. June 19, 1915, Mikulicz's operation for recurrent carcinoma of descending colon. July 27, the opening in the intestines was closed with catgut stitches taken through all the coats. This repair was then reënforced by Lembert stitches of chromic gut. The layers of the abdominal wall were then fastened together, excepting for a very small area which provided for possible drainage from the suture line. Patient left the hospital August 15 with stoma closed.

CASE VII (Roosevelt Hospital).—B-3291. C. A., male, aged sixty-five. September 13, 1912. Patient had an artificial anus in the descending colon, the result of a partial colectomy for diverticulitis. Both afferent and efferent portions of intestine were left in the wound, and the spur between the two had been divided by a clamp. October 13, an incision was made around the fistulous opening liberating the intestines for about one inch from stoma. Catgut stitches were taken through all coats of intestines to close the stoma, and these were reënforced by several Lembert stitches. The layers of abdominal wall were sutured together, excepting for a very small opening to provide drainage from the intestinal suture. Much improvement was obtained by this procedure, but there was still a slight fistula on November 3, which

was closed by a similar operation. The patient left the hospital on December 14, with the wound entirely closed.

CASE VIII.—Boy of twelve. Seen in consultation with Drs. Tilton, Brewer, and Peck, December, 1912. Appendicitis, with abscess formation and peritonitis, followed by post-operative ileus. Secondary operation revealed an obstructive kink in the lower ileum. Temporary improvement followed the relief of this obstruction, but the next day the condition became desperate and, as an emergency procedure, an opening was made in a loop of intestine which presented at the drainage wound. Gas escaped, and at a later time intestinal contents escaped in large amount. This was finally controlled by a flanged catheter. The wound closed spontaneously and recovery followed.

CASE IX (Roosevelt Hospital).—L. D., aged fifty. August, 1913. Six days after a gastro-enterostomy, he developed symptoms of ileus. Vomiting was persistent, and finally had a fecaloid odor. The constipation was complete. Had much distention, and an incision was made in the median line to find the point of obstruction. The small intestine was much distended. The lower part of the large intestine was not distended. No definite point of obstruction could be found. An enterostomy was done in the ascending colon. A large amount of gas escaped. Wound was kept open for three or four weeks, and then closed spontaneously. Complete recovery.

CASE X (General Memorial Hospital).—G. S., aged eighteen. February, 1912. Appendicectomy. Eight days later, ileus, followed by spontaneous rupture of the intestine into the drainage wound. Immediate relief of symptoms. Fecal drainage. Spontaneous closure of fistula. Complete recovery.

CASE XI (General Memorial Hospital).—November, 1912. Operation for abdominal abscess of uncertain origin. Post-operative symptoms of localized peritonitis and intestinal obstruction very severe. Spontaneous rupture of intestine into drainage wound. Prompt recovery, with spontaneous closure of fistula.

CASE XII (General Memorial Hospital).—H. C., woman of forty. October, 1906. The intestinal fistula had been present for several years following an operation in another city. This was closed easily by liberating the intestine, sewing the edges together, reënforcing suture line with Lembert stitches, and supporting this by the abdominal wall sewn in layers.

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TEMPORARY COLOSTOMY

A PRELIMINARY REPORT UPON A NEW TECHNIC

By Harry A. Shaw, M.D.

AND

John Hunt, M.D.

OF SEATTLE, WASH.

As a foreword, the writers of this article wish to state that the primary purpose of submitting the following technic at this time is with the hope that the same will be critically reviewed by surgeons whose opportunities in the greater clinics will enable them to prove the practical worth, either pro or con, of this technic, should the following report with the results of animal experimentation appeal sufficiently to their surgical judgment.

Earlier diagnosis, better understanding of the anatomy (especially of the lymphatics), and improved surgical technic have caused almost total substitution of temporary colostomy plus radical extirpation for permanent colostomy in malignancy of the pelvic colon or rectum. In the writers' experiences, the safe and early closure of the artificial stoma, after it has ceased to perform a useful function, has often presented a more complex, discouraging and dangerous problem than the primary operative procedure.

In the performance of a temporary colostomy the primal considerations are:

1. *Speed.*—This is essential in any operative procedure, but here we are usually dealing with a patient who is far below the average as a surgical risk and consequently speed may spell the difference between life and death.

2. *Protection of the General Peritoneal Cavity.*—It is to be remembered that we are dealing with the most septic portion of the alimentary canal under normal circumstances, which under the usual circumstances calling for colostomy has become a culture tube "par excellence" whose bacterial content has been infinitely multiplied. (This is one of the chief objections to the immediate use of Paul's tube, Collier's apparatus, etc.) In addition to the dangers of sepsis, we have the possible added dangers of cancer cell implantation under certain circumstances.

3. *Prevention of Mucous Eversion.*—This is one of the *chief* factors which retard spontaneous closure of our stoma and is productive of persistent fecal fistula, often more formidable to deal with than the original lesion.

4. *Prevention of herniation and sacculation of the proximal gut.*

5. *Ability to Close the Stoma Soon After it Has Ceased to Perform a Useful Function.*—The ideal would be, of course, to be able to spontaneously close the stoma at approximately a given time.

6. *Conservation of the intestinal lumen* to insure an absence of stenosing injury and its future functional integrity.

7. *To establish an efficient stoma.*

To accomplish the above, there have been innumerable operative procedures and mechanical devices suggested, requiring operation in one, two or even three stages. The writers of this paper believe they

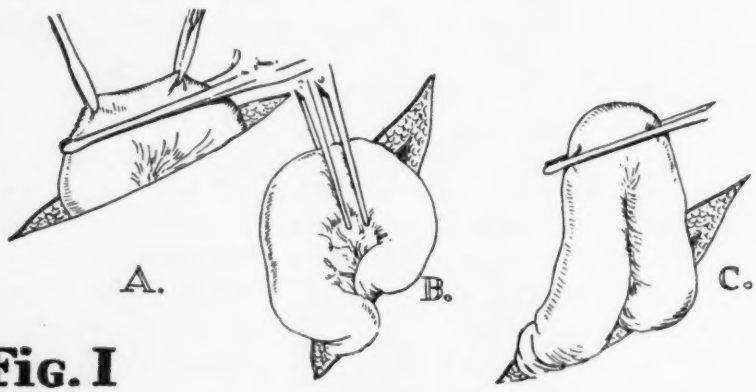

Fig. I

have devised a technic that covers the seven basic requirements as enumerated above, in one stage. The technic is as follows:

Incision, exploration, etc., are just the same as any type. Choice of dealing with the gut, *i.e.*, single-barrelled, double-barrelled or simple attachment of the gut to the peritoneum, is simply a matter of judgment; after such decision we next grasp the gut with a crushing clamp, as per cut Fig. 1, *A, B, C,* according to the type. Within the bite of the crushing forceps is interposed a piece of dentist's rubber dam, the same width as the proposed stoma and about four inches long. The parietal peritoneum is carefully circumstitched around the gut, keeping in mind the longer time the necessity of a functionating stoma is

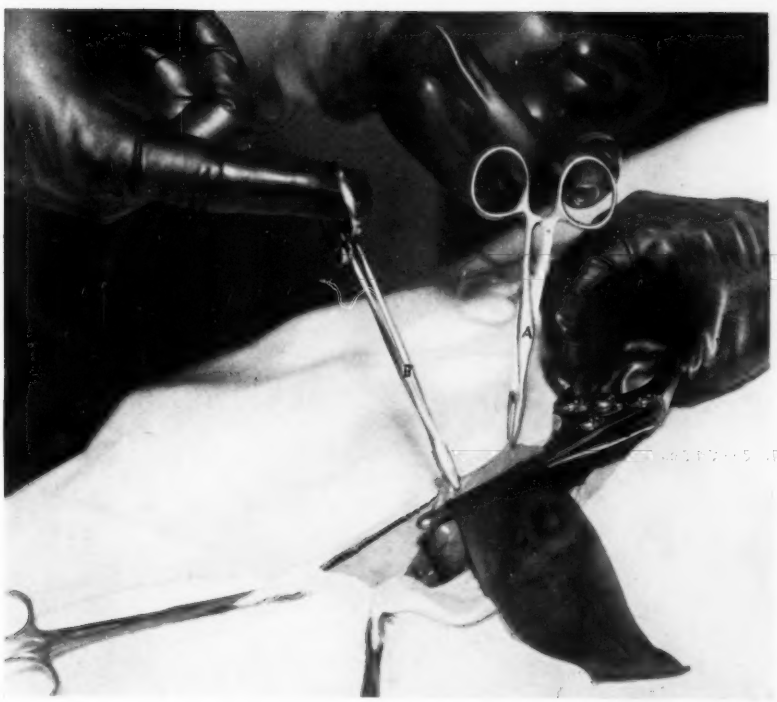

FIG. 2.—Here a Pyor clamp (*E*) (if not convenient, use any form of crushing forceps, preferably with a narrow blade) is applied to the antimesenteric border of the gut, just engaging sufficient gut to insure an ample stoma, avoiding the useless waste of tissue; the forceps engage the gut about one-eighth of an inch longer than the proposed stoma. The rubber tissue (*C*) is cut the exact width of the proposed stoma (the ideal substance is a piece of medium-weight dentist's rubber dam, but if not at hand the wrist portion of an old rubber glove will serve). The gut is picked up at two points, with either Allis or hæmostatic (*A* and *B*) forceps which are held slightly apart by an assistant while the operator applies the crushing forceps with the rubber tissue within the bite.

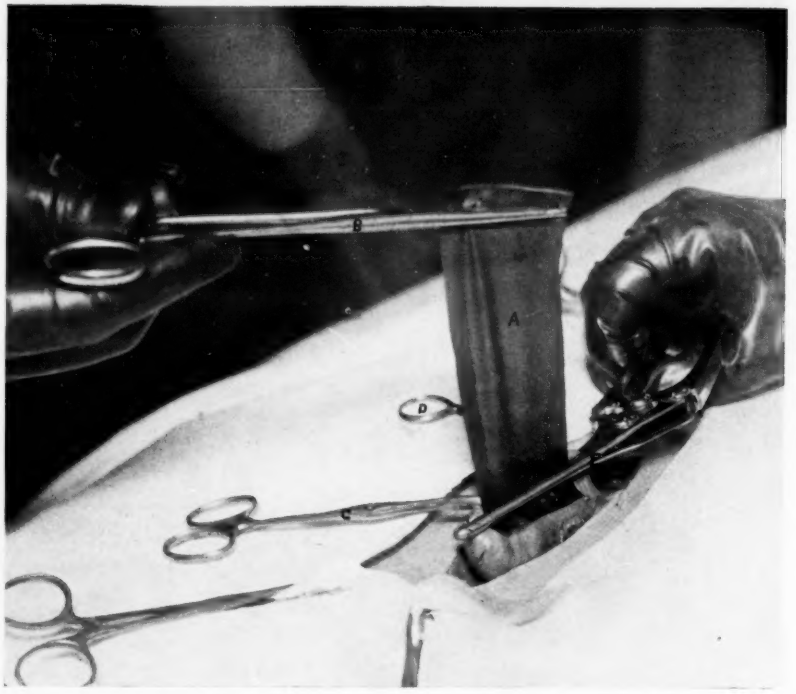

FIG. 3.—This gives a somewhat better view of the rubber tissue (*A*) which is interposed to prevent serous union. Notice the excess that is below the bite of the clamp (*E*); this is trimmed off in the manner illustrated in Fig. 4. It is a waste of time to attempt to apply the clamp just flush with the rubber, as it can be snipped off in the manner illustrated in less time than it takes to tell of the same.

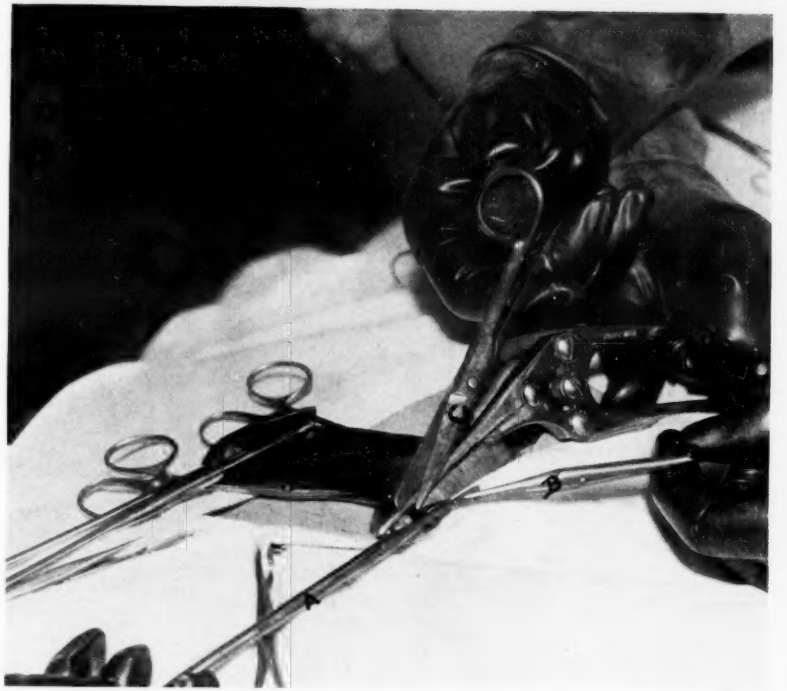

FIG. 4.—Here the excess of rubber tissue, as shown in Fig. 3, is being trimmed away. Take hold of each end of the excess with a hæmostat (*A*, *B*), draw taut and clip with scissors (*C*); by drawing taut the same will contract almost flush with the clamp, as per illustration.

FIG. 5.—Sewing the visceral to the parietal peritoneum. The level at which this is done depends upon the type of colostomy and the length of time you propose to allow the new stoma to functionate, *i.e.*, in a simple temporary colostomy with an estimation of about two weeks desirable functionation, you would sew your visceral and parietal peritoneum close to the clamp, leaving just face enough to apply the Kerr basting stitch. In one where the stoma was to be permanent, or one which was to usefully functionate over a long period, you would suture your parietal to visceral peritoneum at a sufficient distance from the forceps to bring your new stoma upon a level with the skin. The question of the desirability or non-desirability of a spur formation would be guided by the operative indications as in any method.

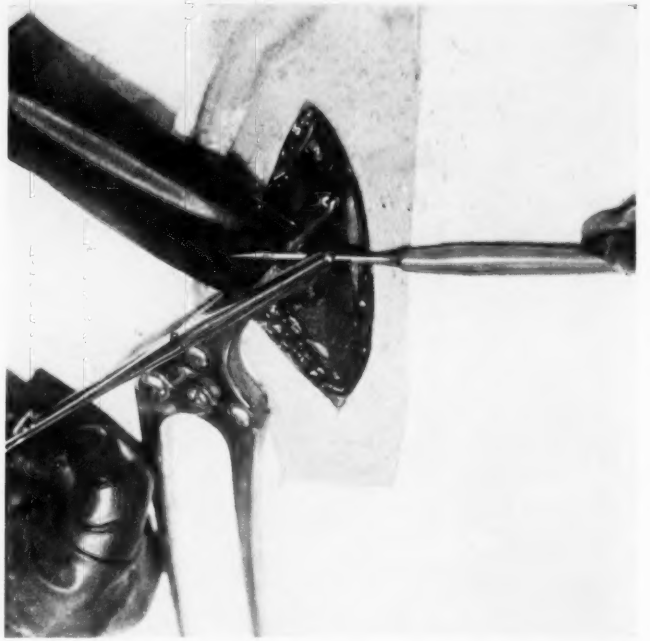

FIG. 6.—Cutting away the gut above the bite of the crushing clamp. First draw the rubber taut to one side and grasp the portion of gut above the crushing clamp (*A*) with a second clamp (*B*) parallel with first one (to prevent leakage). Cut with a sharp knife between the two clamps, cutting away from the rubber tissue so as not to cut the same. After the gut is severed thoroughly, cauterize with carbolic acid, wipe with sponge but do not follow with alcohol.

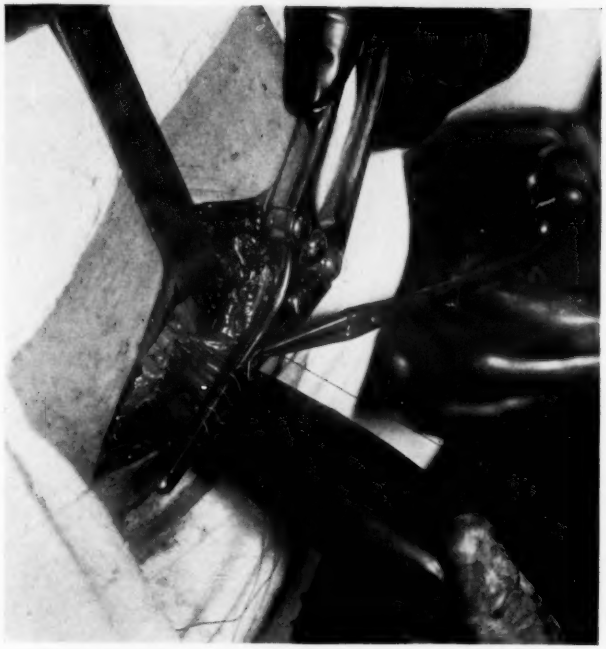

FIG. 7.—Applying Kerr basting stitch. Apply in the same manner just as though the rubber were not interposed, passing back and forth, piercing the rubber with each stitch; this holds the rubber *in situ*. (For the technic of the stitch I refer the reader to "Basting Stitch," etc., by Kerr, of Washington, D. C., published in *Surg., Gynæc. and Obst.*, October, 1913.) Use a curved needle and fairly heavy Pagenstecher. Note the approximation of visceral and parietal peritoneum with small stitches to insure accurate and tight approximation with early union and consequent safety.

FIG. 8.—The two ends of the Kerr stitch (*A* and *B*) are now pulled taut, which causes the complete infolding of the intestinal wall, leaving the rubber tissue interposed to prevent union of the serous surfaces. The two ends of the Kerr stitch are then passed through the entire thickness of the abdominal parietes from within outward, emerging just above and below the upper and lower angles of the wound.

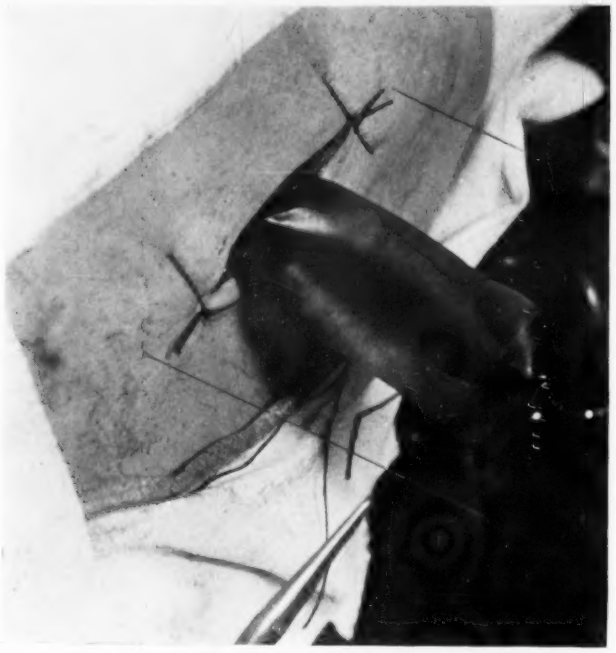

FIG. 9.—The wound is then closed by one silkworm-gut suture above and one below the interposed rubber. The rubber prevents union of the parietes and obviates the necessity of vaseline gauze, etc. It also makes a pathway of least resistance for any possible leakage or infection, *i.e.*, acts as a drain.

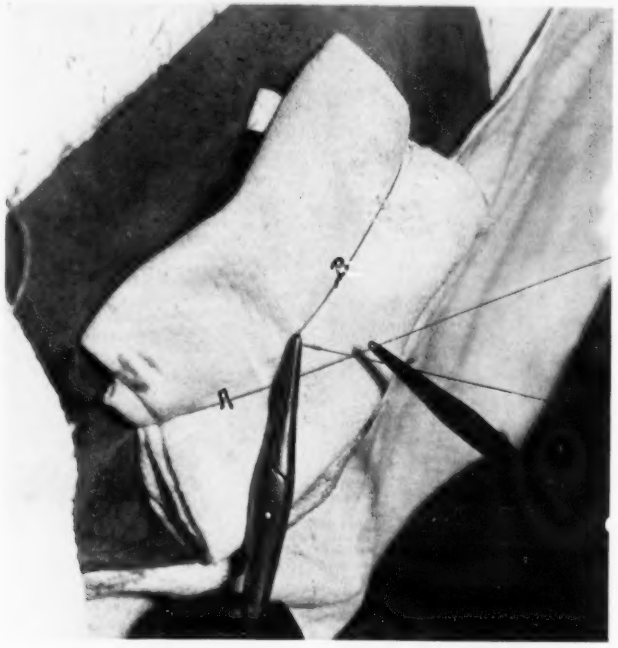

FIG. 10.—Next the excess of rubber is rolled flat between gauze and the Pagenstecher ends (*A* and *B*) of the Kerr stitch are tied fairly snug over another piece of gauze laid over the infolded rubber. Then apply the usual laparotomy dressings.

anticipated, the further away from the crushing forceps the gut is to be circumstitched. Next apply another crushing forceps parallel and distal to the first, then cut between, cauterize with carbolic acid and apply a Kerr basting stitch, the ends of which are brought out through the abdominal wall and tied over gauze. This stitch is to be removed when necessity calls for a patent stoma.

At the end of thirty-six hours, union between the parietal and visceral peritoneum is complete and the basting stitch may be cut close to the skin on one end and pulled out at the other. (As a matter of fact, if you have been careful with the circumstitching of your gut and still leave your rubber *in situ* to act as a drain, the stitch may be taken out safely as early as twelve hours.) After the basting stitch has been removed, the rubber acts as a guide to the stoma, which sometimes remains sealed after the stitch is removed, due to the crushing of the forceps; the introduction of the gloved finger easily overcomes this. The subsequent treatment would be that following any type of colostomy, depending, of course, upon the individual case.

Animal experimentation with this technic has been carried out upon seventeen dogs, with two deaths, neither due in any way to the type of operative procedure. We varied our technic somewhat, but finally concluded the steps, as illustrated in Figs. 2–10, inclusive, to be the simplest, safest and most efficient.

The advantages of this technic are as follows:

1. There is no necessity for any secondary operative procedure to establish a patent stoma, either cutting or burning, both of which necessitate the bringing of gut to the surface, or at least well into the wound. Simply withdraw the basting stitch.

2. The crushing forceps have obviated any possibility of hemorrhage from the gut.

3. The gut may be suspended at any height from the peritoneum to the skin, this governing the rapidity of the after closure.

4. The slight inversion of the serosa, produced by the Kerr suture, has a tendency to remain so after the stitch is withdrawn, due to the serous union at each extremity of the opening caused by the longitudinal initial and terminal stitch of the Kerr suture and to union of the serosa to the parietes. This inversion has the tendency to prevent a mucous eversion and consequently slow healing fistula.

5. The interposed rubber obviates the necessity of any packing with other rubber tissue or vaselined gauze and acts as a drain in case of infection or possible leakage. It also acts as a guide to our newly-formed stoma.

6. The most rigid conservation of intestinal tissue insuring against crippling defects; this is markedly true where the stoma is placed deep.

ILLUSTRATIVE CASE.—Mr. H. A. H., aged sixty-four years, referred by Dr. Richard H. Lion, of Bothel, Washington, operated upon at Providence Hospital, August 26, 1916; *permanent colostomy for inoperable carcinoma of the pelvic colon.* The technic described in the previous pages was employed. The patient left the hospital on the twelfth day and his post-operative convalescence was no more stormy than that of a simple appendectomy. The result was ideal.

FIBROMA OF THE SMALL INTESTINE RESULTING IN INTUSSUSCEPTION

By J. E. James, Jr., M.D.

and

S. W. Sappington, M.D.

of Philadelphia

The purpose of this paper is to contribute a case-report of a fibroma of the small intestine, to emphasize the relation between benign tumors of the intestine and intussusception in adults and to comment briefly on the rarity and collected cases of intestinal fibroma.

Miss A. J., aged thirty-four, stenographer. General appearance of under-nutrition; average weight, 114 pounds. No important infectious features in family or previous personal history.

The patient was first seen in consultation with Dr. Wm. R. Williams, April 20, 1915. Paramount in the history obtained at this time was the severe pre-menstrual pain and the cramps during the first day of each menstrual period; this dysmenorrhœa having become progressively worse, especially within the past six months. Two days prior to the present illness, menstruation had appeared, at the regular time and with the usual degree of distress; the patient being relieved the following day with the full establishment of the flow.

On the morning of April 20, the patient went to her office, but immediately upon arrival was seized with an attack of intense abdominal pain, accompanied by faintness, nausea and weakness. Upon her return home, there were evidences of a mild degree of shock with, at first, a weak, slow pulse, slightly subnormal temperature, pallid face and tender and rigid abdomen. Because of the menstrual history, some pelvic condition was suspected.

Examination, made three hours after the initial attack, revealed a tense abdomen, generalized tenderness, marked rigidity but no distention. The temperature was normal, pulse 90, regular and strong. Pelvic investigation was difficult; a small anteflexed uterus could be outlined in an anterior position; the adnexa were not distinctly palpable; there was no lateral tenderness or enlargement. There were no gastric symptoms present and an enema just prior to the examination had secured an apparently normal evacuation. There were the physical signs of a mitral stenosis, but the patient had not suffered symptomatically from it.

A tentative diagnosis of ovarian cyst twisted upon a pedicle was made and the hospital advised. Upon admission to the Hahnemann Hospital in the early evening, the temperature was 99.4° F., pulse 72, the pain decidedly lessened and the abdomen less tender and rigid. There was no nausea or vomiting. With this improvement, operative interference was postponed. During the night the patient was comfortable without narcotics and took small quantities of liquids without distress. Toward morning, there was some hiccoughing. In the early morning, hiccoughing was pronounced and there was increasing rigidity of the abdomen with beginning distention. Temperature was 98.2° F., pulse 84. Immediate operation was approved.

The operative incision was in the midline below the umbilicus. Upon opening the peritoneum, there immediately protruded a number of distended, darkened coils of small intestines knotted together in a cluster or mass, at the base of which the omentum, twisted, formed a firm, tight, constriction band. To free these coils, it was necessary to incise the omental ring. This done and the " mass " separated, an intussusception of the ileum was noted. With careful traction, 55 cm. of gangrenous, foul, invaginated gut was withdrawn, and at the distal end of the released intestine a small, hard nodule was felt. Clamps were applied in suitable healthy areas at either end of the necrosed gut, inclusive of the nodule, and the part removed. The free ends of the gut were ligated, invaginated and closed with a purse-string suture. A lateral anastomosis was then made, the mesentery sutured and the abdomen closed without drainage.

Upon reaction, the patient was placed in the upright position and a continuous proctoclysis of normal saline solution begun. Hiccoughing persisted for the first two days with some nausea, slight distention and severe abdominal pain. Peristalsis was audible on the second day: the temperature was normal and the pulse rate 92 on the third day. On the fifth day, a low enema was given and fecal matter and considerable flatus obtained. The abdominal wound healed by primary union and the patient was allowed to sit up on the fourteenth day. Two days later, a mild phlebitis involving the left leg developed. The case was discharged from the hospital thirty-four days after operation.

Subsequent to operation and in the light of its findings the patient was further interrogated regarding her history. It was elicited that constipation had been increasing in severity for the past four years. During this time, there were attacks of malaise, a " general sick feeling," and some indefinite abdominal distress not relieved by bowel evacuation. For the last three months, the constipation had been exceedingly distressing and accompanied by

loss in weight. Occasionally, the patient had noticed bright blood in the stool, but attributed it to hemorrhoids.

Eighteen months after operation, the patient is up and about but in somewhat delicate general health. Her abdominal condition, however, is excellent and she suffers no gastro-intestinal symptoms except constipation, which still persists but in lessened degree.

Pathologic Examination.—The specimen consists of 60 cm. of discolored, gangrenous small intestine with a small tumor a few centimetres from one of the resected ends. The tumor is a reddish, hard, smooth, roughly spheric nodule, projecting into and occupying a considerable portion of the lumen of the ileum from an attachment exactly opposite to that

FIG. 1.—Silhouettes of tumor and intestine (natural size).

of the mesentery. The growth measures 2.4 x 1.9 x 1.9 cm. and it attached by a broad base measuring 1.8 cm. (see Fig. 1).

Microscopically, the tumor is a hard fibroma arising from beneath the outer muscular layer of the gut and pushing the various coats before it in its projection into the intestinal lumen. Fasciculi of fibrous tissue run in all directions and blood-vessels are numerous. The muscular layer of the gut acts as a sort of a capsule to the tumor and above this is the necrotic and atrophied submucosa and mucosa, with only shadow effects of the normal cellular structure. There are numerous dilated capillaries in the mucosa and submucosa. Beyond a slight degree of hyalinization, there is no degeneration apparent in the tumor proper.

Discussion.—Malignant growths of the bowel become clinically apparent in many ways and only rarely through causing intussusception. On the other hand, benign tumors of the intestine attract attention almost solely through the intussusception which they induce. Excepting those growths of the rectum and sigmoid which may be seen or felt, they are for the most part clinically silent as far as suggestive symptoms are concerned. It is true they give rise to constipation and abdominal pain, but such symptoms are common to so many conditions as to be of no diagnostic significance. Bleeding is more suggestive but frequent and common to other lesions. It is also possible that the tumor may be felt through the abdomen as in Watson's [1] case or give rise to obstruction without intussusception as in Dewis's [2] and Fenger's [3] cases, but these findings are so rare as to be of little or no value.

The importance of the relation between intussusception and benign tumors of the intestine is seen in the fact that many cases are reported as intussusception rather than tumor; and even when the title head of a report reads tumor of the intestine it usually includes mention of intussusception. Kasemeyer,[4] in his exhaustive article on "Tumor Invagination of the Intestine," states that, in searching the literature, he was astonished at the large number of cases of intussusception due to tumor. That the vast majority of cases of intussusception is not due to tumor and that this vast majority occurs in infants and children is, of course, well known. But in subjects past seven years of age, tumors of the intestine are etiologic factors to be considered. Eliot and Corscaden [5] analyzed 300 cases of intussusception in adults and found 100 cases due to tumor. Stetten [6] states that in 60 per cent. of 67 cases of intestinal lipoma in which symptoms were present, an invagination existed. Kasemeyer collected 208 cases of invagination of the gut due to tumor. He reports altogether 284 cases, but 76 of these were not due to true tumors, 60, for example, arising from inverted appendices and diverticula.

Though malignant growths are very much more common than benign tumors of the intestine, the percentage of invaginations is higher in benign than in malignant neoplasms, showing conclusively the far greater tendency of benign tumors to induce intussusception. Of Eliot and Corscaden's 100 cases, 60 per cent. were benign and 40 per cent. malignant. Of Kasemeyer's 208 cases, 55.75 per cent. were benign. It is difficult to say whether one variety of benign tumor exhibits a greater tendency to induce invagination of the gut than another. It is much more likely a matter of the size, weight, situation and form of the tumor rather than the special variety. The tendency of benign internal intestinal tumors to grow in pedunculated or polypoid form is favorable

to the induction of intussusception in contrast with the infiltrating growth of malignant neoplasms.

Fibroma is one of the rarer benign neoplasms of the intestine. One finds isolated reports of angioma, lymphangio-endothelioma, lymphadenoma, papilloma and cyst, but of the relative common and important tumors such as fibroma, lipoma, myoma and adenoma, the fibroma is the least frequent. Dewis found only only 5 fibromas in collecting 219 benign intestinal tumors. Adenomas, if one adds the polyps which are usually of adenomatous structure, are so common as to be seldom reported unless multiple and causing complications. Hake,[7] in 1912, collected 58 cases of intestinal myoma, adding 23 to Steiner's [8] 35 cases. Stetten, in 1909, collected 74 cases of the submucous or internal lipoma. We were able to find reports of 24 fibromas of the intestines.[12–35] Of these Dewis collected 4 and added one of his own. Eliot and Corscaden collected 11. Kasemeyer reports 8, but one of these, that of Greig Smith, was mentioned by Eliot and Corscaden. Means and Forman [9] report one of their own. And the one reported herewith makes the total 25. A number of cases listed as fibroma of the intestine do not qualify as such. Pantzer's [10] " Fibroma of the Intestine Eventuating in Intussusception and Obstruction " is not a fibroma at all, but a myoma, the only mention of fibroma being in the title. The report of Alexander [11] on " Intestinal Obstruction Due to Fibroma " is an account of a uterine fibromyoma and not an intestinal tumor. The " fibroma " of F. S. Watson mentioned in Means and Forman's paper is spoken of by Watson as a " fibro-adenoma of the inner wall of the ileum," but he states that the specimen was mislaid before a thorough histological examination could be made and so its nature is doubtful. In our list we have strictly excluded fibromyomas or myofibromas, classing them with the myomas. We have admitted myxofibroma and myxoma. We have also listed an adenofibroma and a pedunculated fibropapilloma which seemed to meet requirements. Our own case was a pure hard fibroma.

The results of operation in fibroma of the intestine are very encouraging, especially when it is considered that so many of the cases are complicated by intussusception and require resection. Of the 25 cases collected, 22 were operated and of these 16, or 72.7 per cent., recovered.

Summary.—A hard fibroma of the ileum causing intussusception and successfully operated with resection of the intestine is herewith reported. Benign neoplasms of the intestine are relatively frequent causes of intussusception in adults. The rarity of fibromas among the infrequent benign intestinal tumors is seen in the fact that the authors were able to collect only 25 cases. Of 22 cases operated, 72.7 per cent. recovered.

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TRANSACTIONS
OF THE
PHILADELPHIA ACADEMY OF SURGERY

Stated Meeting, held November 6, 1916

DR. GEORGE G. ROSS in the Chair

GUNSHOT WOUND OF THE CAROTID ARTERY

DR. E. G. ALEXANDER narrated the history of a man, twenty-six years of age, who was admitted to the Episcopal Hospital, August 6, 1916, with a gunshot wound of the neck. The wound was on the right side of the neck, one and a half inches above the clavicle and one and a half inches to the right of the median line. There was a large swelling on the right side of the neck that extended from the clavicle almost to the angle of the jaw. The trachea was pushed over to the left and on a line with the angle of the jaw. There were periodic discharges of a considerable quantity of blood from the wound, and with each of these discharges the size of the swelling in the neck was appreciably diminished. The patient was slightly shocked, dyspnœic, cyanotic and emitting a frothy mucus from the mouth. He could only speak in a whisper. There was no wound of exit but the bullet could be felt subcutaneously to the right of the vertebral border of the left scapula and about on a line with the fourth rib.

The patient was immediately taken to the operating room and operated upon under ether anæsthesia plus the administration hypodermatically of morphine sulphate, grain ¼, and atropine sulphate grain 1/150.

An incision was made along the anterior border of the sternocleidomastoid. The tissue was so infiltrated with blood that the usual landmarks of the neck could not be made out. The incision was deepened and immediately on opening the deep fascia blood gushed forth in a continuous stream. As the flow of blood was so profuse it was impossible to locate any structures or bleeding points. The wound was therefore rapidly enlarged down to the clavicle. Hæmostatic forceps were then thrust at random into the wound and clamped, gauze sponges were also packed into the wound. These two procedures controlled the bleeding to a certain extent. By rapidly removing the gauze packs and quickly inserting another the bleeding point was proved to be at the

lower angle of the wound underneath the clavicle. Long curved hæmostats were clamped in the wound underneath the clavicle where the bleeding seemed to be coming from. After several attempts the bleeding was controlled.

As the patient had lost a large quantity of blood his condition was most serious. An intravenous injection of normal salt solution and adrenalin was given.

As many hæmostats were clamped in the wound the next step consisted in removing as many as possible and ligating the bleeding points. Hæmostat after hæmostat was removed until only a few remained and these were over the line of the common carotid and innominate arteries. The tissues were then exposed and it was found that these arteries were clamped. The carotid was ligated and the hæmostats on it removed. There still remained three long curved hæmostats underneath the clavicle, and as it was impossible to pass a ligature around them it was decided to leave them as clamped. The intravenous injection failed to show any beneficial effects, as the patient was blanched and pulseless. It seemed as if he would die on the table. The officer who accidentally did the shooting was fortunately at hand, and after explaining the patient's condition to him he readily consented to give some of his blood. A transfusion of 750 c.c. was done by the Kempton-Brown method. The patient's condition immediately improved. He gained some color and it soon became possible to feel his pulse. The wound was closed with the three-curved hæmostats left *in situ,* supported by a small packing of gauze. The patient was sent to his bed greatly shocked.

After operation (August 6, 1916).—Patient greatly shocked. Recovered from ether quickly, complains of little pain, given stimulation and started on enteroclysis.

7.00 P.M.: Temperature 102, pulse 126, respirations 28. Pulse of much better quality. Given hypodermoclysis, one pint every six hours.

August 7, 1916: Kept mildly under the influence of morphine sulphate. Had a fair night. Can speak only in a whisper. Pulse rapid. Temperature 103.3. Takes enteroclysis poorly. Complains of intense thirst.

August 8, 1916: Temperature down, pulse better, respirations slower. Kept under the influence of morphine sulphate.

August 9, 1916: Given water by mouth, enteroclysis given intermittently. Lies quietly on back. Dressings, which were blood soaked, changed.

August 10, 1916: Temperature 99; pulse 100. Very quiet, lying on back. No pain. Condition satisfactory.

August 13, 1916: Taken to operating room and hæmostats unclamped, but as bleeding began they were reclamped.

August 14, 1916: Has developed pain in the left chest, friction rub is heard.

August 16, 1916: Pleurisy better.

August 17, 1916: Taken to operating room and hæmostats unlocked, slight bleeding resulted. This was controlled by lightly packing the wound with gauze.

August 21, 1916: Patient taken to operating room and hæmostats removed. Slight bleeding again occurred which was controlled by packing. Still has pain in the left chest. Has developed a few râles.

August 22, 1916: Bled a small amount last night which was controlled by pressure. Has developed a pulsating tumor under the line of incision.

August 23, 1916: Bled from the wound again last night, controlled by packing.

August 24, 1916: Pulse suddenly became worse and the patient died in a few minutes.

An autopsy was performed by the coroner's physician and it was found that the bullet had taken the following course: Entering the right side of the neck one and a half inches above the clavicle and one and a half inches to the right of the median line, it passed down and back, partially severing the carotid at its junction with the innominate, it then passed through the edge of the third dorsal vertebra, pierced the fourth rib, and lodged underneath the skin as previously described.

In the wound in the neck was a large traumatic aneurism. In the left thorax was a pint of fresh blood and it was the opinion of the one performing the autopsy that death was due to this hemorrhage and that it was caused by a rupture of the fourth intercostal artery. The rupture of this artery was due to a spicule of bone on the fourth rib.

The reporter added that Thompson (*So. Surg. and Gynec. Trans.*, 1914, vol. xxvii, p. 110), in an excellent article entitled "Ligation of the Innominate Artery for Cure of Subclavian Aneurism," reports a case of his own, reviews the literature on the subject and records in detail all cases operated on for ligature of the innominate since 1880.

Since Thompson's article, Carl A. Hamann (*Cleveland Med. Jour.*, 1916, xv, p. 221) has reported two cases as follows:

CASE I.—*Subclavian aneurism.*—Colored male, aged twenty-five years. Operation, ligation of innominate and common carotid. At time article appeared, which was two months after the operation, the patient was well.

CASE II.—Female, aged fifty-nine years. A fusiform aneurism of the innominate at its junction with the common carotid and subclavian. Operation, ligation of the innominate. The patient died the fourth day after operation of cerebral anæmia.

Nearly all the cases reported were operated for spontaneous aneurism and the remaining few for traumatic aneurism or injury to the artery.

Harte (ANN. SURG., 1897, vol. xxvi, p. 488) reports a case of injury to the common carotid due to a pistol wound. The innominate and common carotids were ligated in this case.

Leutas, Hermandez and Saigo report cases of injury to the carotid and subclavian, requiring ligature of the innominate.

Of the 52 cases collected by Thompson, forty-one were operated for spontaneous aneurism, 6 for traumatic aneurism, and 5 for wounds of large arterial trunks. Of this number, 16 recovered.

Secondary hemorrhage and cerebral anæmia were the most frequent causes of death.

A summary of the cases reported in the literature up to date and including the present case is as follows:

	Cases	Rec.	Died
Ligation of innominate alone	37	7	30
Ligation of innominate and carotid simultaneously	16	10	6
Ligation of innominate, carotid and vertebral simultaneously	2	0	2
	55	17	38

DR. JOHN SPEESE said that he had recently operated upon a patient with an unusual stab wound of the neck. The patient, a colored man, had been stabbed with a large butcher knife, the blade penetrating the tissues of the neck for a distance of about six inches. The man was almost exsanguinated from the constant flow of blood from the wound, the hemorrhage had been partially controlled by packing. The wound, enlarged under novocaine anæsthesia, was found to extend from about the middle of the left sternocleidomastoid muscle, some fibres of which were cut, to the sternoclavicular articulation. The jugular vein was seen but was uninjured. Toward the bottom of the wound there was a discharge of frothy blood, evidently due to an injury to the apex of the lung. The hemorrhage from the lung was easily controlled by packing, and the patient returned to the ward. On the following day he had

a slight elevation of temperature, and on examining the chest the left side was found to be clear and resonant, whereas, the opposite pleura contained all the signs of an exudate extending to the angle of the scapula. The effusion was gradually absorbed, the patient making an uninterrupted recovery. The case is reported because of the small amount of damage inflicted by a knife of such size and because of the production of a pleural effusion on the right side when only the left apex of the lung and pleura seemed to be injured.

STAB WOUND INTO THE RIGHT AURICLE OF THE HEART

Dr. Chas. F. Nassau reported the history of a young man, nineteen years of age, who was admitted to St. Joseph's Hospital on September 26, 1913, while Dr. J. Chalmers DaCosta was on ward duty. The reporter happened to be operating at the moment of his admission, so that the care of the patient in emergency fell to him.

History.—During an altercation the patient had received a thrust in the left upper portion of the chest from a keen narrow-bladed fish knife some three inches in length. He was quickly brought into the hospital by the patrol wagon and transferred speedily to the operating room.

The wound of entrance was in the third interspace on the left side, about one inch from the edge of the sternum. The patient's pulse was extremely weak and the pulse rate so rapid that it could hardly be counted.

Under light ether anæsthesia an incision was first directed along the left border of the sternum for a distance of about three inches, including the third and fourth ribs. From this sternal incision, two others were made laterally from either extremity of the perpendicular incision. These lateral incisions over the intercostal space were about three inches in length. Trap-door of chest wall was then raised up to the outer side. In turning up the flap of the chest wall, the pleural cavity was opened. When the pericardium was exposed, it was seen to be filled with blood, which was oozing from a small wound. The pericardium was incised. Upon opening the pericardium, blood gushed out in great quantity, making it very difficult to determine exactly where the heart had been injured. Quick sponging showed the wound to be in the anterior surface of the right auricle, about five-eighths inch in length. A fine silk suture was inserted at the upper angle and tied, after which four continuous stitches were taken. No attention was paid to the phase of the heart cycle during suturing. After placing this suture, it was necessary to introduce two interrupted sutures of fine

black silk, to check some oozing along the suturing line. After cleansing the pericardial sac, an iodoform gauze drain covered with gutta-percha tissue was inserted at the junction of the vertical and lower horizontal incisions. A second drain was placed in the pleural cavity alongside of the drain into the pericardium. Through-and-through silkworm-gut sutures were used to close the wound. The patient stood the operation very well and at the close his pulse rate was of good volume and had dropped to slightly over ninety.

The wound healed by primary union, the pericardial drain being removed first at the end of about forty-eight hours. The pleural drain was removed in four days. Convalescence was smooth but in a few days patient began to run an irregular temperature with physical signs of pleural effusion on the left side. On October 6th, a piece of the sixth rib on the left side was resected, and about two quarts of septic pleural effusion evacuated. With the exception of the irregular temperature, which lasted for some time, he made a complete recovery and was discharged from the hospital on November 29, 1913, in a very satisfactory condition.

The reporter added that his experience in this case was that there cannot well be any chosen time in the heart cycle for the introduction of sutures, for the heart in this instance was merely a quivering mass of flesh without determinable systole or diastole. He now believed it was unnecessary to put a drain in the pleural cavity. He was certain that it was necessary to drain the pericardium, for it is much better to finish the operation quickly than to spend too much time in cleansing the pericardium, and there must be, of necessity, considerable blood behind the heart to be drained out. In this patient, the drainage was profuse for the first twenty-four hours, and upon removing the drain there was a considerable gush of blood-stained fluid.

Through the kindness of Dr. Willis F. Manges, he had an X-ray made last week, more than three years after injury, showing the entire thorax. Dr. Manges reports that there are no adhesions of the lung to the diaphragm, and that, except for a slight defect in the sixth rib, he would be unable to state that any operation had been performed upon this boy. There is nothing to show where the ribs were divided along the sternal margin.

STAB WOUND INTO THE LEFT VENTRICLE OF THE HEART

Dr. J. F. Jones reported the history of a young man, aged eighteen years, who was admitted to St. Joseph's Hospital, April 18, 1916, at 3.00 P.M. He had plunged a large and not especially clean penknife into

his chest about fifteen minutes before reaching the hospital. The patient walked into the dispensary from the patrol wagon, a distance of about twenty-five feet, and placed himself upon the examining table with little or no assistance.

From the amount of blood on the patient's clothing, it was judged that the hemorrhage must have been quite profuse, but upon cutting away his shirt, no blood whatsoever was issuing from the stab wound. There was a small wound in the fourth insterspace about one inch internal to the midclavicular line. Pulse was 148, of fairly good volume and regular at first, but later showing a tendency to intermit. The temperature was not taken. Patient was ordered to the operating room, and while being prepared became unconscious. Fifteen minutes had elapsed from the time of his admission to the time that he became unconscious, or one-half hour from the time of stabbing. Five minutes more elapsed before the commencement of the operation. When the incision was begun, thirty-five minutes after the infliction of the wound, the patient's pulse could not be felt and he was apparently not breathing.

A vertical incision was made to the left of the sternum, beginning at the second rib and extending downward for about five inches; the cartilages were cut through, and at each extremity of this vertical incision, a horizontal incision was made in an intercostal space extending about three inches in the direction of the midaxillary line. The flap thus formed was turned upward and outward by fracturing three ribs.

The pericardial sac was found distended and the heart was not beating. There was a very small puncture wound in the sac low down. When the pericardium was opened, a large amount of blood, both clotted and liquid, gushed forth and immediately thereafter the heart began to contract violently and with great rapidity. There was a small puncture in the heart near its left margin, close to its apex and extending into the ventricular cavity. The wound in the heart was slightly larger than the one in the pericardium. Three interrupted silk stitches were introduced into the ventricular wall and the pericardium was sutured with a continuous silk stitch, a small opening being left at the lower angle of the pericardial incision and the sac drained by a small piece of plain gauze. The pleural cavity, which had been opened, was also drained by gauze. Nearly a quart of salt solution was introduced intravenously during the operation.

The patient was on the operating table about three-quarters of an hour. At 8.30 A.M. of the morning following the operation, temperature was 98, pulse 110, and respiration 50. Respiration remained at 50 for three days, and gradually descended to normal. Gauze drain was

removed from pericardium on the fourth day and from pleura on the thirteenth day. There was a stitch infection at the upper and outer angle of the skin flap. The patient was discharged from the hospital on the seventy-seventh day after operation.

His present condition is best expressed by the reports of Dr. Willis F. Manges and Dr. Ross V. Patterson, both of whom have examined the patient quite recently, October 5, 1916.

Dr. Patterson reports that the patient " complains of occasional moderate degree of precordial pain, some dyspnœa on exertion, and at times a rapid heart. A careful examination failed to reveal any gross abnormal signs of cardiac damage, or disturbance in the mechanism of cardiac contraction. A walk of two miles at an ordinary gait was accomplished without undue fatigue. There was a moderate degree of cardiac impairment for unusual effort. The pulse at rest was 78, systolic pressure 115, diastolic pressure 85. There was no evidence of displacement, enlargement, or dilatation. The area of visible cardiac impulse was visible from the second to the fifth interspace within the midclavicular line. Systolic retraction at the apex in the fifth interspace in the anterior axillary line was probably due to pericardial adhesions."

The report of Dr. Manges is as follows: " Fluoroscopic observation reveals a normally pulsating heart except that the rhythm is somewhat disturbed. There is practically no deviation in the position of the heart. The diaphragm moves freely on both sides, and is free from adhesions. Stereoscopic plates show that the third, fourth and fifth ribs have been fractured, about one inch or more external to the ostochondral junction. They are united by bony union with considerable angulation. There is no evidence of disease of the lung tissue or of fibrous tissue formation. The heart seems to be a little above the average in size."

CASES OF INFECTIOUS ARTHRITIS

Dr. William Jackson Merrill related the history of a patient who had every symptom of tuberculous arthritis of the hip—muscular spasm, rigidity, tenderness on motion and the systemic symptoms. There was a history of tonsillar infection, followed by arthritis of the left hip with the usual symptoms, and it was under desultory treatment for nearly a year, the hip-joint improving not a bit. The patient came to the University Hospital and was sent to the nose and throat department where the tonsils were removed, shortly after which the hip began to improve. A plaster bandage was worn for protection and in about

eight months the hip-joint had almost normal motion. In a year motion had entirely returned and the tenderness had entirely disappeared.

Also the history of a child who had a recurrent arthritis in the opposite hip after removal of tonsils. There was periarticular thickening about the right hip with marked muscular spasm and tenderness on motion. Immediately following tonsillectomy the joint began to improve. About a year ago she began to have trouble in the other hip-joint. She was sent to the nose and throat department where no tonsillar trouble was reported. The adenoids, however, were removed and the hip-joint disease entirely disappeared—a coincidence since it was proven that there was no throat infection and that the adenoids had nothing to do with the recurrence.

The third case had a very acutely affected right knee. There was muscular spasm; practically no motion; much tenderness and swelling, but without very marked general systemic disturbance. Under rest and treatment the patient improved slightly. The tonsils were removed. After a stay in the hospital of two or three weeks the disease subsided and the patient went home with a plaster bandage from the crests of the ilia to the toes, which he wore for a short time. There is now absolutely normal motion in the knee-joint and no tenderness.

In two other cases, boys of the same family, he saw the first seven years ago when he had a very acutely affected hip with the usual local and systemic symptoms, and the family was told that the child had a tuberculous hip-joint disease. The hip-joint was absolutely rigid; the X-ray showed no organic changes, but there was a great deal of periarticular thickening, the tonsils were so enlarged that they almost touched each other. They were removed and in six months the hip-joint disease was much improved. Pain on motion had nearly subsided but there was still some restriction of motion. In about fourteen months he could walk normally.

The second boy had a polyarthritis, the left hip being practically stiff; he could move the right hip slightly. His knees were also quite rigid. One shoulder-joint and his wrists were affected. His throat was in the same condition as his brother's and the tonsils were likewise removed. Now, while there is some slight enlargement in the wrists, the joints are flexible. The boy was treated for a year and a half in the nose and throat department.

In yet another case the patient was admitted to the hospital July 28, 1916, with the knee in the condition shown with apparently a good deal of organic change. Under rest and treatment all symptoms disappeared and there is no evidence now of any joint irritability except a

slight roughness on one side of the epiphysis of the femur which he did not believe represents organic change.

Dr. Merrill added in reply to questions, that laboratory examination of the tonsils removed was not routinely carried out in these cases. All the work attending the removal of the tonsils was done in the nose and throat department, and so far as the bacteriological examination is concerned they had no report. The tonsils were, however, reported cryptic and containing pus. Some of the cases reported, and others of the 40 or 50 on record at the dispensary, seem to prove that the tonsils were an etiological factor. Some of the cases which presented recurrent arthritic attacks in the same or other points at intervals of from six to eighteen months recovered entirely after removal of the tonsils. The first and fourth cases had such a history. Some of the cases were not admitted to the hospital for treatment but had their tonsils removed and measures for the improvement of the general health were carried on at home, treatment of the throat being administered in the nose and throat dispensary; it would seem, therefore, that these cases, having recovered after the local infection, were not tuberculous but due to the septic infection of the tonsils.

So far as the test for tuberculosis is concerned he did not know how a positive conclusion could be reached. Von Pirquet himself said that his test is worthless after the age of four and all surgeons know the value of the subcutaneous and intracutaneous tests. Tuberculous joint disease has a pretty definite course and history, and persists even after the removal of tonsils, adenoids, teeth and, in fact, the correction of any other trouble. It presents a picture which is recognized by experience and which is unmistakable. The general and local symptoms during the onset are entirely different in tuberculosis when compared with the septic. The manifestations in and about the joint, even in the very beginning, in the case of tuberculosis show trophic changes which do not appear in the septic. A mild case of tuberculosis might be mistaken for septic arthritis. In many of his cases the hygienic conditions had been good. He did not feel, therefore, that the hygienic surroundings in these cases were important. It is said, that certain cases recover without having the tonsils removed. Similarly many cases of tonsillitis get well, the disease coming on quietly and after a time subsiding, with no concomitant joint disturbances. At other times joint affections occur with attacks of tonsillitis and get well after the subsidence of the tonsillar disease. Again joint diseases follow tonsillar infection, become subacute or chronic and persist for an indefinite time.

Regarding the relationship of the involvement of the joint and the

epiphysis in the cases studied, he had rarely seen epiphysial involvement.

Dr. Gwilym G. Davis said that in comparatively slight cases it is impossible to prove absolutely the existence of an infectious cause. In recent years the dependence of arthritic troubles upon infection has in a few cases been demonstrated as a certainty, and in a larger number of cases with a certain degree of probability. Many cases, however, are not sufficiently marked to enable us to localize the origin of infection. The doctrine of infection as a cause of chronic joint disease has, however, gained ground. Particularly in the older case reported the question of a metabolic cause may arise as in the hypertrophic arthritis of adults. In young cases such as those shown by Dr. Merrill, the metabolic cause would not be so probable. In those, of course, one would consider the possibility of traumatism without infection, and specific infections such as syphilitic and tubercular. Joint troubles are gradually being systematized and when not simply traumatic are usually found to be tuberculous, or infectious, and disturbed metabolism as a cause seems to be losing ground.

Dr. A. Bruce Gill said that the diagnosis of the cause of arthritic conditions in children often presents a difficult problem. The Von Pirquet test done routinely usually will be found positive except in very young children. Often by putting these children at rest in bed with extension their symptoms quiet down and they are discharged from the hospital wearing a case and walking on crutches. As time passes they acquire good motion, and upon examination the joint is apparently normal. All have seen many arthritic cases clear up without treatment except putting the patient at rest and without excision of the tonsils. Orthopædic clinics are flooded with arthritic cases of all kinds and in these days the theory of focal infection is greatly emphasized. Every effort is made to discover and to remove the source of such infection. Notwithstanding the fact, however, that patients are referred to the nose and throat and gynæcological departments and to the dentist and elsewhere for removal of such focal infection, in many cases the arthritis remains unchanged.

Dr. P. G. Skillern, Jr., thought Dr. Merrill's series of joint infections to be instructive because of the clear relationship he has established between effect and cause, as was demonstrated by the prompt improvement and ultimate cure after the tonsils were ablated *in toto*. He said ablated *in toto* in order to "knock" those operators who are satisfied with performing partial tonsillectomy by means of the tonsillotome. This is a procedure that is about as logical as removal of a portion of the appendix for appendicitis. There is no reason to suppose

that the outer, or buried, portion of the tonsil is any less diseased than the inner, or exposed, portion—a conclusion that the operation of partial tonsillectomy presupposes. As a matter of fact both bacteriologic and pathologic-histologic examination of totally ablated tonsils show that the outer, or buried, portion of the tonsils is also involved in the disease of the inner portion, which is more evident to the naked eye at the time of physical examination, and that this outer portion exhibits no such immunity to disease as the partial tonsillotomists would have us believe. Nay, more: recent investigations have shown the *capsule* of the tonsil—the outermost portion—is frequently diseased, particularly in tuberculosis, so that any operation must be discarded which does not remove the capsule together with the tonsil.

Dr. Merrill described a case of metastatic arthritis of the hip-joint in which recrudescence followed "removal of the tonsils." This recrudescence suggests the probability of the tonsils not having been wholly removed—an inference that seems more logical than the essayist's adenoid hypothesis, for he did not see how adenoids with their smooth and œdematous mucosa could act as portals of entry for bacteria, unless the adenoids were the seat of ulcerous processes the result of trauma.

The pathology of Dr. Merrill's cases was probably not sufficiently extensive, judging by the short clinical course, to warrant the use of so comprehensive a term as "arthritis." The term "serious synovitis" would doubtless apply, the bacterial emboli lodging in the subsynovial vascular layer and by their toxins irritating the sensitive synovial layer itself until a serious effusion—at first bacteria-free—is poured into the joint cavity from the congested membrane.

Given a case of joint disease, it often requires a painstaking and exhaustive study to detect and establish the primary focus of infection. The work of Rosenau in the bacterial, and of Pemberton, of Philadelphia, in the non-bacterial or metabolic joint-disease, has already shed much light upon the pathogenesis and successful treatment of these respective lesions.

ACIDOSIS IN SURGICAL CONDITIONS

Dr. J. Harold Austin said that normally CO_2 is present in the tissues at a tension of about 80 mm.; in the alveoli of the lungs and in the arterial blood leaving the lungs, at a tension of about 45 mm. Every unit of arterial blood as it passes through the tissues takes up a certain load of CO_2 as a result of this difference in tension, and reaching the lungs loses this CO_2 there. When there is a diminution in the "buffer substances" of the blood there is a diminution in the amount of CO_2

which each unit of blood can take up in response to a given increase of CO_2 tension. In consequence there follows a diminished removal of CO_2 from the tissues and among others from the respiratory center. The accumulation of CO_2 results in a higher CO_2 tension in the center and this in a stimulation of the center with increased alveolar ventilation so that the center may have a CO_2 tension of what we will suppose 85 mm. and the alveoli of the lungs of 30 mm. The difference of CO_2 tension between the pulmonary alveoli and the tissues will thus have been increased from 35 mm. to 55 mm. Now it is possible that in spite of the diminished "buffer substances" in the blood the amount of CO_2 taken up by each unit of blood under the influence of this increased difference of CO_2 tension will be sufficient to maintain an adequate transfer of CO_2 from the tissues to the lungs and establish an equilibrium upon this new basis.

To recapitulate: The CO_2 carrying capacity of the blood is diminished for a given difference in CO_2 tension. This interferes with the removal of CO_2 from the tissues, including the respiratory center. This stimulates the respiratory center, leads to hyperpnœa and an increased pulmonary ventilation. This increases the difference of CO_2 tension between tissues and pulmonary alveoli, and this in turn increases the amount of CO_2 carried by each unit of blood and re-establishes an equilibrium.

The only clinical feature characteristic of these cases is the peculiar deep respiration without cyanosis with the usual association of headache and frequency of vomiting. It is the very inability to recognize acidosis on the symptom-complex alone which makes the tests for acidosis of value, and it is our knowledge of these tests which will enable us to detect unsuspected cases of acidosis.

Dr. Astley P. C. Ashhurst said that the laboratory men and the physicians in the last few years have brought the surgeons to the realization of the fact that starvation, among other things, is a potent cause of acidosis. When we see children in the wards who are homesick and do not eat, we do not operate on such children until they become accustomed to their surroundings, when they begin to eat and get better. Surgeons did not formerly recognize that anæsthetization and operation on such patients before this improvement occurred, might result in the death of the child from acidosis. He recalled one such case in which death occurred a number of years ago, following a double osteotomy for knock-knees. We then thought it a case of status lymphaticus: the child's temperature rose rapidly after operation, respiration was exceedingly rapid, and she died within a few hours. Autopsy showed nothing

very conclusive. No doubt death was due to acidosis. This patient starved herself before operation because of her unhappiness and homesickness. There can be no doubt that in many cases in the past, where we have thought death was the result of the operation, it was really due to acidosis; and that the fatal termination might have been averted if operation had been postponed. Acidosis, as pointed out by Crile, is greatly to be feared in cases of advanced peritonitis; and in such cases it is often acidosis and not bacterial intoxication that is responsible for the patient's death.

EXPERIMENTAL CHEMOTHERAPY OF BACTERIAL INFECTIONS

DR. JOHN A. KOLMER, by invitation, read a paper with the above title.

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ANNALS *of* SURGERY
227-231 S. 6th Street
Philadelphia, Penna.